AERO ENGINES
VOLUME II.

AERO ENGINES

VOLUME II.

CONSTRUCTION, INSTALLATION, RUNNING AND MAINTENANCE

BY

VARIOUS AUTHORS

With 194 Illustrations, and 12 Folding Diagrams
(5 in Colour).

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PREFACE.

In presenting Volume II of this Treatise, the Publishers do so with full confidence in the usefulness of the Contents and the way it has been set out. It has been altered from the original layout, as previously notified in Volume I, as it has been felt strongly that the interests of the Ground Engineer and Student will be served best—not by a slavish and of necessity, abbreviated, inclusion of every manufactured type and make of engine, so much as by a full treatment of selected examples of each widely adopted generic type—upon which almost all ground engineers will be engaged, and knowledge of which will serve as a basis for work on all engines of that type, *e.g.* radial.

The Sections into which the book has been divided are:—I.—Radial. Part 1.—Medium Power. Part 2.—High Power (Advanced Design). II.—In-Line. Part 1.—Medium Power. Part 2.—High Power (Advanced Design). III.—Vee. High Power (Advanced Design).

The subject matter on each engine has been written specially for the book, and the work has been done either independently by a Technical Expert connected with the particular engine maker's works, and with that manufacturer's authority, or officially, by the Technical Publications Department of the Company.

Great care has been taken to include illustrations which will be really useful. Many show the constructional details and independent assemblies, while others show various operations and ' rigs,' special tools in use, etc., and these will be found valuable in connection with practical work. A full Routine Maintenance Table is given for each engine.

In the first projected layout, which is referred to above, it was intended to have independent chapters on Carburation, Ignition, etc., but for the practical man it will prove far more valuable now that these subjects have been incorporated at the appropriate points in the section on each engine. This means that Ground Engineers will have first-hand information on the particular carburettor, magneto, etc.—its individual installation layout, care and adjustment, on the engine he is dealing with.

So far as the " Series " of the selected engines is concerned, the examples can be considered to show ' fundamental characteristics,' and therefore to require knowledge and technique which will serve as a basis for practical

work on all Series. For in most cases the main differences between fundamental and subsequent Series are concerned with increased power rating—with necessary changes in compression-, supercharger gear-, and reduction gear-ratios, and general strengthening to cope with higher stressing—rather than with basic changes in design. Where there are differences which justify special mention, however, this information has been supplied.

It will be noted that, although the ground covered is the same, there are slight variations in the detail arrangement in the Sections, but these are due to the fact that various Authors have been engaged on the book, and the Publishers have not wished to interfere with any individual styles or choice of order.

It must be pointed out that only in the case of the lowest powered and simplest type has it been possible to include a full "Schedule of Fits and Clearances." It would certainly have been the Publishers' wish to include this information for all engines, but it will be appreciated that the very lengthy Schedules of the larger and more complicated types would have necessitated an expansion of the book—and its cost, far beyond its aim. It is felt, however, that the usefulness of the particular Schedule which has been included will outweigh any criticism which might be directed to the omissions. Such Schedules are available independently in the majority of cases.

The omission of the sleeve-valve engine—undoubtedly a type of which much will be seen in the future—is on account of the scarcity of reliable operational information. As an aeroplane power-unit it is in its infancy, and, until lengthy and exhaustive service tests have been made and it emerges from the present experimental stages, it is considered inadvisable to include the type.

In conclusion the courtesy of loans of block and blueprint from the Publishers of "The Air Annual" and "Machinery," respectively, is fully acknowledged.

C. G. & Co., Ltd.

London, *March*, 1939.

CONTENTS.

SECTION I.—RADIAL

SECTION II.—IN-LINE

SECTION III.—VEE

LIST OF ILLUSTRATIONS.

SECTION I

Part 1.—ARMSTRONG-SIDDELEY "CHEETAH"

Part 2.—BRISTOL "PEGASUS"

SECTION II

Part 1.—DE HAVILLAND "GIPSY MAJOR"

Part 2.—NAPIER " DAGGER "

SECTION III

ROLLS-ROYCE " KESTREL "

TABLES

AERO ENGINES

SECTION I. RADIAL.

PART 1.—ARMSTRONG SIDDELEY—" CHEETAH."

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Technical Publications Dept., Armstrong Siddeley Motors, Ltd.

INTRODUCTION.

The Cheetah IX. engine is the result of very careful and progressive development from the original engine of this range which was produced in 1932. This method has proved so successful that the engine in question is perhaps the most popular from a training point of view that this Company has ever turned out; it may, in fact, be considered as a worthy successor to the Lynx, of which there are some hundreds installed in training aircraft and doing excellent service after years of hard work in all parts of the world.

The Cheetah IX. engine is fitted to such well-known aircraft as the Avro " Anson," which is to be found in service in Great Britain, Egypt, Finland, and Ireland, while other aircraft with the same type are being used in Holland, Brazil, France, Portugal and other countries.

Unfortunately, space does not permit us to go too deeply into the details of this engine from an assembling point of view, but it is hoped that the following notes on maintenance, together with the description of the engine and its lubrication system will be of service to those for whose use this book is intended.

SPECIFICATION.

Type	7-Cylinder, Aircooled, Radial.	
Induction System	Geared Fan, Ratio 6·52 : 1.	
Drive to Airscrew L.H. Tractor	Direct.	
CYLINDER.		
Bore	5·25 ins.	133·3 mm.
Stroke	5·5 ins.	139·7 mm.
Swept Volume (Total)	834 cu. ins.	13·65 litres.
Compression Ratio	6·35 : 1.	
BOOST.		
Rated	Plus ½ lb./sq. in.	
Max. Permissible (M.P.B.)	Plus 2½ lb./sq. in.	
Max. Cruising	Minus ½ lb./sq. in.	
Max. Economical Cruising	Minus 1 lb./sq. in.	

SPEED (R.P.M.)

Normal - - - - - - -	2100
Maximum - - - - - -	2425

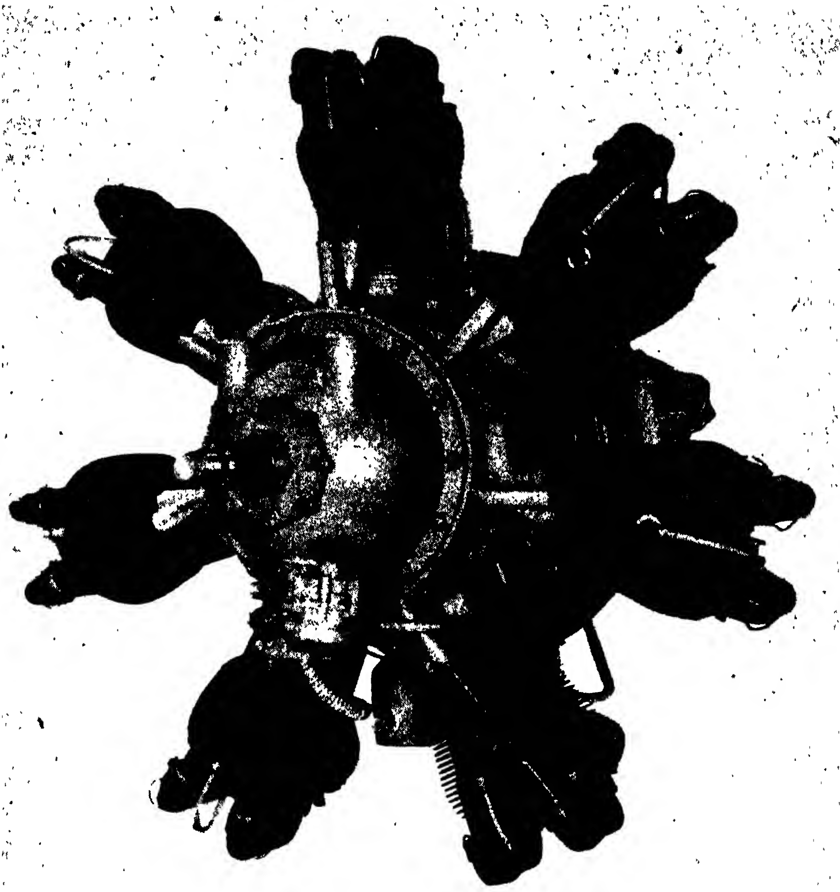

Fig. 1.—The CHEETAH IX. engine.

ENGINE POWER (H.P.) ·

Rated at Normal Speed - - -	310 at 6000 ft.	
Max. at Max. Speed and Rated Boost	350 at 7300 ft.	
	Rated Boost.	M.P.B.
At Sea Level and Normal Speed -	289	340

FUEL.

Consumption at Economical Cruising Conditions (Max.)	2100 R.P.M. at Minus 1 lb. Boost 0·49 Pts./B.H.P./Hr.
At Max. Cruising Conditions	2100 R.P.M. at Minus ¼ lb. Boost 0·6 Pts./B.H.P./Hr.
At Max. Level Conditions	2425 R.P.M. at Plus ½ lb. Boost 0·65 Pts./B.H.P./Hr.
At Max. Take-off	2100 R.P.M. at Plus 2½ lb. Boost 0·75 Pts./B.H.P./Hr.
Specification	D.T.D. 230. Octane Value 87.

OIL.

Pressure	65 lb. sq. in.
Consumption at Max. Cruising Conditions	2100 R.P.M. at Minus ¼ lb. Boost 4-8 Pts./Hr.
Specification	D.T.D. 109.
Inlet Temperature	70°C. Normal Maximum. 90°C. Tropical Maximum.

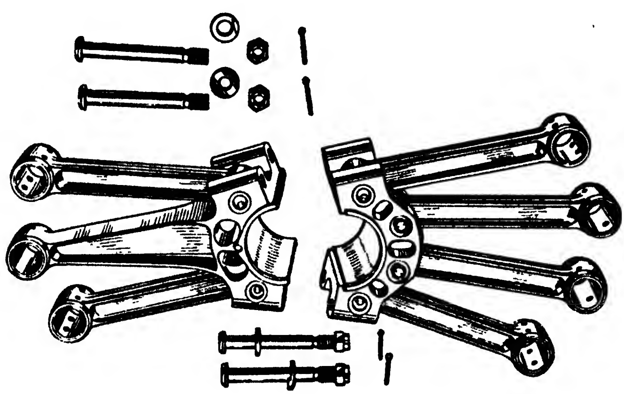

Fig. 2.—The Master Rod assembly.

Engine Speed Indicator Drive	1/4 Engine Speed.
Method of Starting	Hucks, Hand/Electric.
Carburettor	Claudel Hobson A.V.70 M.
Magnetos (2)	B.T.H. SC. 7-1.
Sparking Plugs	K.L.G. V. 14-1B or 918-2B.
Speed of Generator Drive (if fitted)	1·75 or 2·5 Engine Speed.

AVERAGE WEIGHTS OF ENGINE.

Bare and Dry	635 lbs.	286 Kg.
Airscrew Hub	14½ lbs.	6·57 Kg.
Complete with Hand/Electric Starter, Motor, Coil, Airscrew Hub, Hucks Claw, Fuel Pumps and Generator Drive	683 lbs.	309 Kg.

Engine Dimensions.

Diameter (overall) - - - -	47·7 ins.	1210 mm.
Length.		
(*a*) Bearer face to rear of airscrew hub	22·225 ins.	565 mm.
(*b*) Overall (with starter and generator drive) - - - -	52·9 ins.	1343 mm.
Engine Bearer.		
(*a*) Diameter of bearer face, overall	26 ins.	661 mm.
(*b*) Diameter of pitch circle of bolt holes - - - - - -	25 ins.	635 mm.
(*c*) Number and size of holes - -	16-13/32 in. dia.	10·32 mm. dia.

Accessories.

Hand/Electric Starter - - - -	12 lbs.	5·44 Kg.
Motor and Coil - - - - - -	8 lbs.	3·65 Kg.
Hucks Starter Claw - - - -	3 lbs.	1·36 Kg.
Fuel Pumps (2) - - - - -	$5\frac{1}{4}$ lbs.	2·38 Kg.
Generator Drive - - - -	5 lbs.	2·27 Kg.

DESCRIPTION.

The Cheetah IX. is a seven cylinder, aircooled, radial engine with its cylinders equally spaced round a barrel type crankcase.

The engine comprises five main components: the front cover and oil pump, the crankcase and cylinders, the supercharger and induction casing, the induction casing cover, and the auxiliary drives and carburettor.

The crankcase houses the one-piece crankshaft, the master and the six auxiliary connecting rods. The former is a one-piece steel forging of the single throw type having a brass balance weight fitted to each crankweb. The master and auxiliary rods are both steel stampings, the former high tensile steel and the latter air hardened steel. Lead bronze bearings in steel shells are employed and are fitted to the big end of the master rod and cap. They are prevented from turning in their housing by a dowel peg in the rod which engages with a corresponding recess in the bearing shell. Fixed phosphor bronze bushes are fitted to each end of the auxiliary connecting rods, those at the gudgeon pin ends being drilled to provide adequate lubrication.

The master rod, which operates in connection with No. 1 cylinder at the top of the engine, and the cap half are secured to the crankpin by means of four bolts. The six anchor pins used to secure the auxiliary rods are of two kinds, four are grooved and are held in position by the four bolts mentioned above. These grooved anchor pins carry the auxiliary rods for Nos. 2, 3, 6 and 7 cylinders. The remaining two anchor pins which secure Nos. 4 and 5 connecting rods are of the plain type and are a light driving fit in their housings. Each plain pin has a shoulder on it so that it can only be fitted in one way and it is secured by a circlip at each end bedding in a groove cut in the housing in the cap.

The master rod bolts are prevented from turning by a locating washer fitted below the bolt head which is so formed so that its inner side beds into a recess in the cap, while a flat on its outer side mates up with one of the flats on the bolt head.

The crankshaft revolves in two roller bearings, one carried in a steel housing shrunk in the front face of the crankcase and the other, in similar housing, in the diaphragm plate separating the crankcase from the induction case. The crankshaft thrust ball-race is pressed into the front cover, and further secured by the interference fit of the thrust plate. The crankshaft is splined at its forward end to accommodate the airscrew hub, while a spring loaded locking device is fitted to its front extremity to secure the hub in position. This device embodies a spring loaded plunger serrated on the outside and these serrations engage with similar internal serrations cut in the bore of the shaft, in fact the whole device is very similar to that which

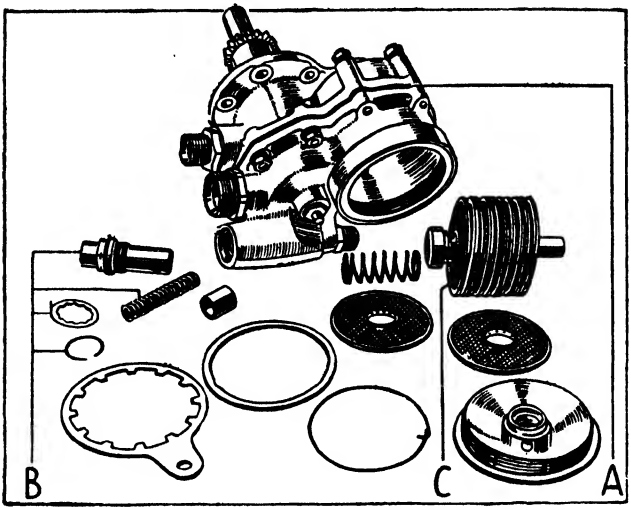

Fig. 3.—The oil pump group.

" A " the oil pump casing ; " B " the relief valve group, and " C " the pressure filter elements and centre tube.

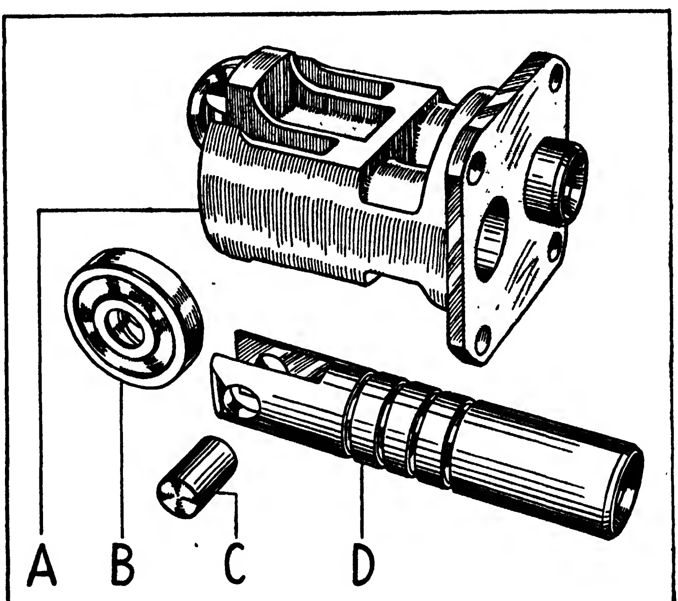

Fig. 4.—A valve tappet and guide in detail.

" A " the guide with a tappet in position ; " B " the tappet roller, and " C " its pin ; " D " the tappet.

is employed on certain types of vehicles to lock the detachable wheel to the hub.

A two-stage oil pump is fitted to the under-side of the front cover, and this consists of pressure pump, scavenge pump, multi-cell oil filter and a relief valve. The two pumps are driven by a bevel gear which meshes with a dished bevel driving gear bolted to the forward face of the cam drum.

The cylinder assembly comprises a high tensile steel barrel screwed and shrunk into an aluminium alloy head, the two parts being further secured by a drilled locking ring. Cylinder head cooling is ensured by deep, close-pitch finning and the locking ring mentioned above acts as an additional cooling element. The nickel chrome manganese valve seats, bronze sparking plug adaptors, and adaptors for the buried type thermo-

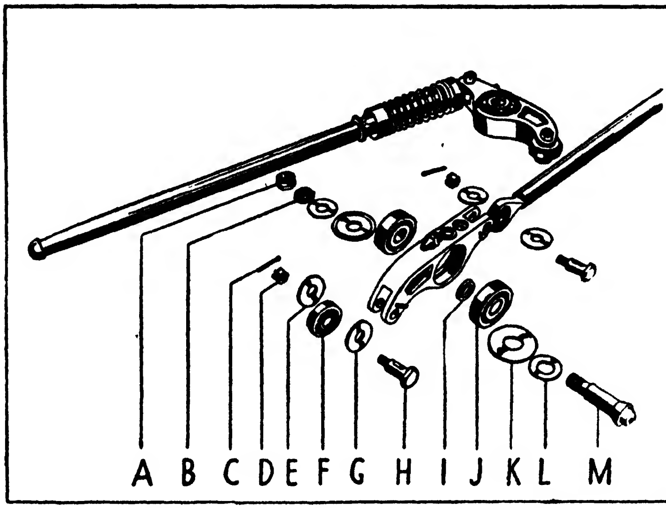

Fig. 5.—A push rod and rocker in detail.

" A " cone locknut ; " B " inner cone nut ; " C " rocker striker split pin ; " D " rocker striker locknut ; " E " rocker striker distance piece ; " F " rocker striker roller bearing ; " G " rocker striker distance piece ; " H " rocker striker roller pin ; " I " centre bearing distance piece ; " J " ball race ; " K " dust excluding shim ; " L " distance shim ; " M " rocker eccentric fulcrum pin.

couple are also screwed and shrunk into the cylinder head, the sparking plug adaptors being further secured by dowel pins. Two valves are fitted to each cylinder, the exhaust valve being sodium cooled ; the valves are operated by push rods and rockers and are fitted with double valve springs.

The assembly of the valve and its springs consists of a steel collar fitted next to the cylinder head recessed to receive the inner ends of the two valve springs. The springs are slipped over the valve stem followed by the top spring retainer. The springs are depressed by means of the special tool provided and the split cotter is slipped into place, care being taken to see that projections in the two halves locate correctly with the groove cut in the valve stem. A circlip is fitted to the inlet valve stem to prevent it falling into the cylinder in the unlikely event of the spring retainer breaking.

The push rods are operated by tappets, the rollers of which run on a two-track cam having four lobes on each track. A spur gear keyed to the crankshaft and further secured by the cam drum locknut, drives a train of three satellite gears. Three pinions keyed to the same shafts as the satellite gears take up the drive but are in mesh with a stationary sun gear with internal teeth, the latter being bolted to the forward face of the crankcase. By this means the necessary reduction is obtained to allow the cam drum to revolve at 1/8th crankshaft speed. The cam drum and crankshaft both revolve in the same direction, *i.e.*, clockwise. In this connection it should be noted that the cam drum is supported on two roller bearings. The satellite gears and pinions are carried on plain phosphor bronze bushes. The push rod consists of a light steel tube into the two ends of which the eye and the ball end are fitted. These are both pressed in and are not welded or otherwise secured. The eye end forms the outer race for the rocker needle-roller bearing.

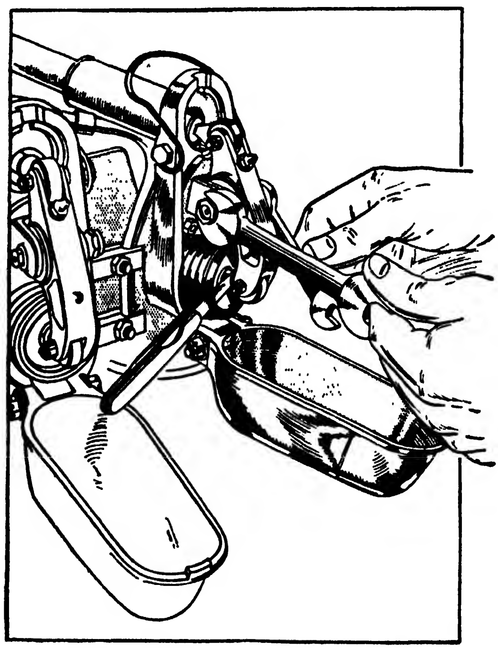

Fig. 6.—Adjusting valve clearances.

Valve rockers are carried in brackets which float in the top of the cylinder head, while the standard carrying the bracket is anchored at the bottom of the head. This method provides a means of automatically correcting the valve clearance to suit varying cylinder temperatures. Two ball races are pressed into the centre of each rocker, having two shims on each side, the larger (inner) shims act as grease retainers and dust excluders while the smaller shims take up end play. Adjustment is effected by means of an eccentric on the rocker fulcrum pin. A needle roller bearing, the inner

race of which is provided by the rocker pin, connects the push rod eye end to the rocker, while the striker at the valve end of the rocker consists of a second needle roller bearing. The valve gear is totally enclosed.

The cylinders are secured in the crankcase by steel adaptors threaded internally to correspond with a thread on the cylinder barrels; they are fitted into the crankcase cylinder mouths and prevented from turning by a locking peg and circlip. A flange on the base of the adaptor bedding on the inner face of the crankcase mouth locates the adaptor when the cylinder is screwed home. The cylinder is locked by the two bevelled sides of the cylinder barrel locking ring which bear, when tightened, one against the crankcase mouth and the other against the lip on the cylinder barrel.

The method of fitting the cylinders is a special one only to be found on Armstrong Siddeley engines and a short description of how this is done will probably be of interest. Twelve unequally spaced holes are drilled in the adaptor to permit the fitter to centralise the cylinder correctly when a new cylinder or adaptor is being fitted to the engine. The procedure is as follows:—

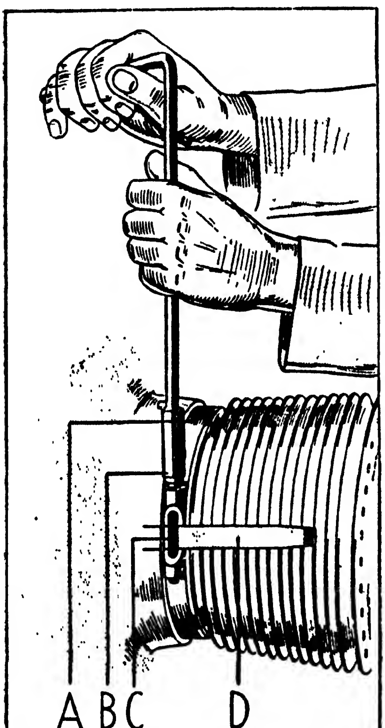

Fig. 7.—Tightening a cylinder.

"A" the locking ring; "B" the spanner; "C" the locking screw, and "D" the gauge for checking the gap in the ring.

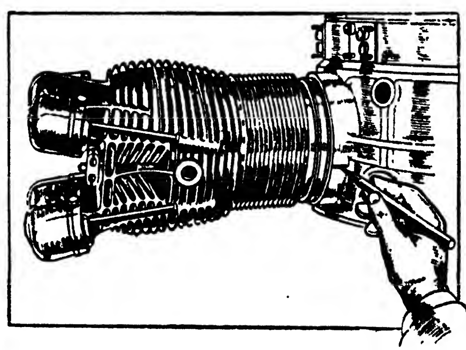

Fig. 8.—Setting the cylinder adaptor.

Shewing the mark made on the crankcase to indicate the position of the centre of the cylinder.

The adaptor is fitted into the crankcase cylinder socket and located by fitting the locking peg through the hole in the socket and through any one of the holes in the adaptor, the peg being then secured by its circlip. The cylinder is then fitted with its locking ring and the set screw on the latter is screwed up till the gap in the ring is between ⅜ in. and ½ in. On screwing the cylinder into the adaptor it may be found that the front side of the cylinder is not, as it should be, parallel to the front side of the crankcase.

In this event note where the centre of the cylinder comes in relation to the front face of the crankcase and mark the cylinder socket accordingly. Now remove the cylinder and mark the adaptor to correspond with the mark on the socket. Remove the adaptor locking peg, turn the adaptor so that the mark made on it comes nearest to the front face of the crankcase and refit the cylinder, which should now be correctly positioned. When

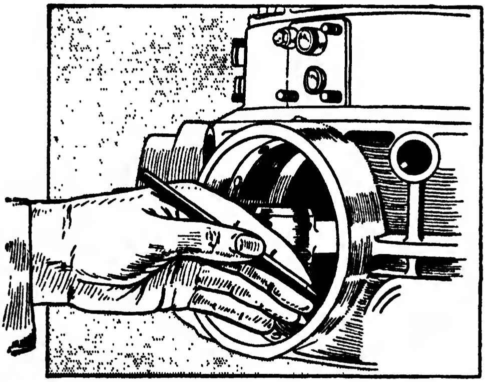

Fig. 9.—Marking the adaptor for resetting.

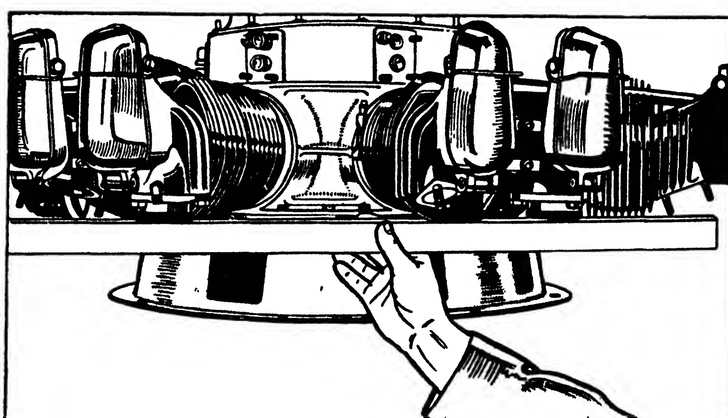

Fig. 10.—Lining up cylinders with straight edge.

all cylinders are fitted they must be lined up by means of a straight edge.

The flat topped pistons are machined from " Y " alloy stampings and are formed with circular ribs in the interior of the crown, for strengthening and cooling purposes. They are fitted with fully floating hollow gudgeon pins retained in position by circlips sprung into the outer ends of the piston bosses. Each piston is fitted with four rings ; one compression ring nearest the crown, two 1° angle rings above the gudgeon pin boss, and a double

scraper ring at the bottom of the skirt. Pistons and cylinders are identical but should not be interchanged. They are numbered clockwise 1 to 7 when viewing the engine from in front.

A diaphragm plate bolted and spigotted to the rear face of the crankcase, with a brass shim interposed to prevent fretting, closes the rear end of the crankcase and carries the housing and outer race for the crankshaft rear roller bearing. This housing is formed with seven dogs which, when the housing is pressed into position from the rear, engage with corresponding slots in the plate. The housing is secured by a locknut on the forward side of the plate which is then peaned over.

The bearing outer race is then pushed in from the rear and secured by a ring sprung into a groove cut in the front end of the housing bore.

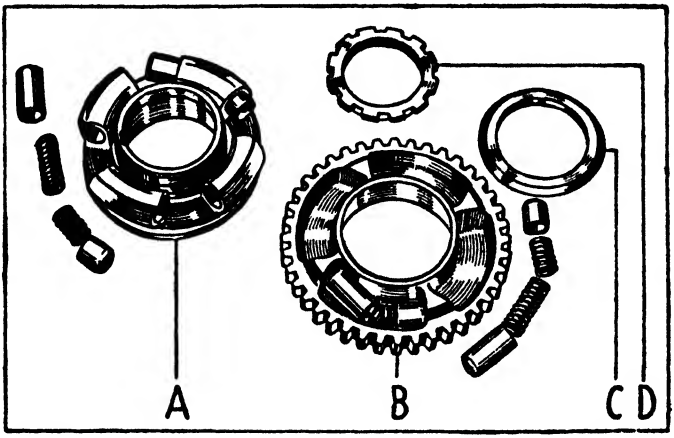

Fig. 11.—Details of the crankshaft spring drive.

"A" the driving member; "B" driven member and crankshaft rear gear; "C" bevelled washer and "D" locknut.

The rear end of the crankshaft protrudes through the diaphragm plate and carries the spring drive, which absorbs torsional oscillations, and the crankshaft rear gear, from which supercharger and auxiliaries are driven.

The spring drive unit is made up of two halves. The forward half or driving member is provided with a flange, on to which the inner race of the crankshaft roller bearing is tapped, and carries the housings for the springs and plungers. These are made in two lengths, the longer plungers and springs taking the drive, while the shorter ones deal with the rebound shocks. The rear half of the unit or driven member is integral with the crankshaft rear gear and carries the buffers against which the plungers butt.

The crankshaft rear gear engages with the fan layshaft pinion which, through the medium of a slipping clutch, drives the fan layshaft large gear which in turn engages with the fan driving gear located on the fan spindle. The rear drive shaft is formed with external splines on its forward end which engage with internal splines cut in a phosphor bronze bush pressed into the rear end of the crankshaft.

The slipping clutch above referred to takes up acceleration and deceleration loads and consists of four phosphor bronze pads located in a housing

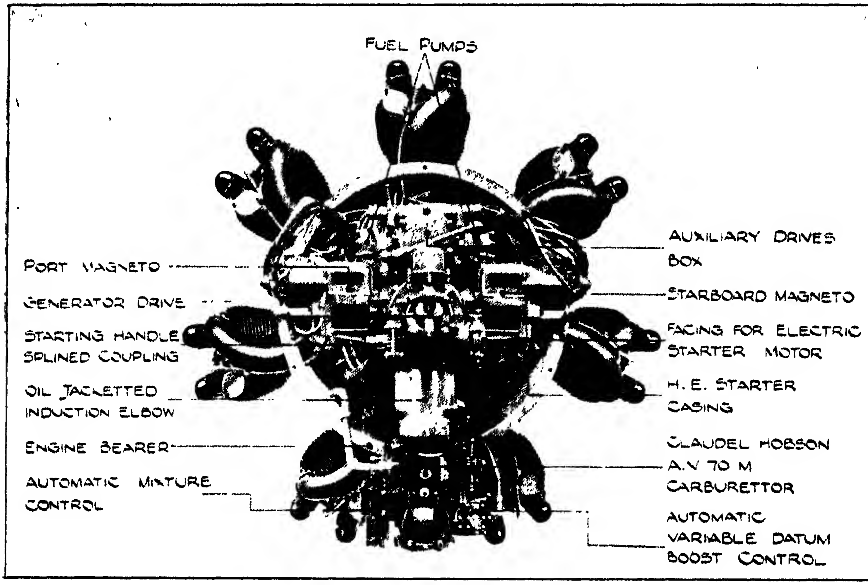

Fig. 12.—Rear view of engine showing the disposition of the auxiliaries on the rear cover.

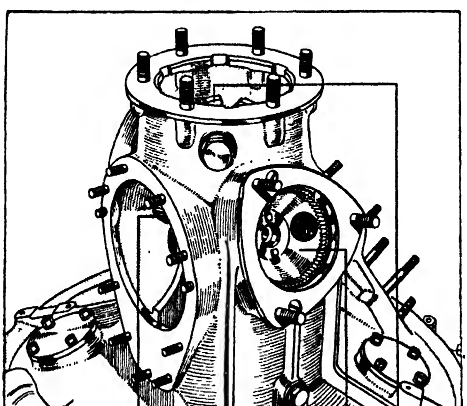

Fig. 13.—The rear drive shaft in position in the rear cover with " A " the auxiliary drive box facing " B " one of the magneto drive housings, and " C " the starter dog.

in the fan layshaft large gear. These pads are six in number and are so formed that when placed together they form a circle so far as the outer circumference of the set is concerned. Both front and rear faces are bevelled off at an angle of 30° towards the outer edge so as to engage with a channel cut to a similar taper in the circumference of the housing in the gear. This channel, however, is somewhat narrower than the width of the pad so that the latter can only enter the channel up to a certain point and cannot bottom. The inner edge of each pad is formed with three slots, making eighteen in all and these engage with the eighteen teeth cut on the fan layshaft pinion.

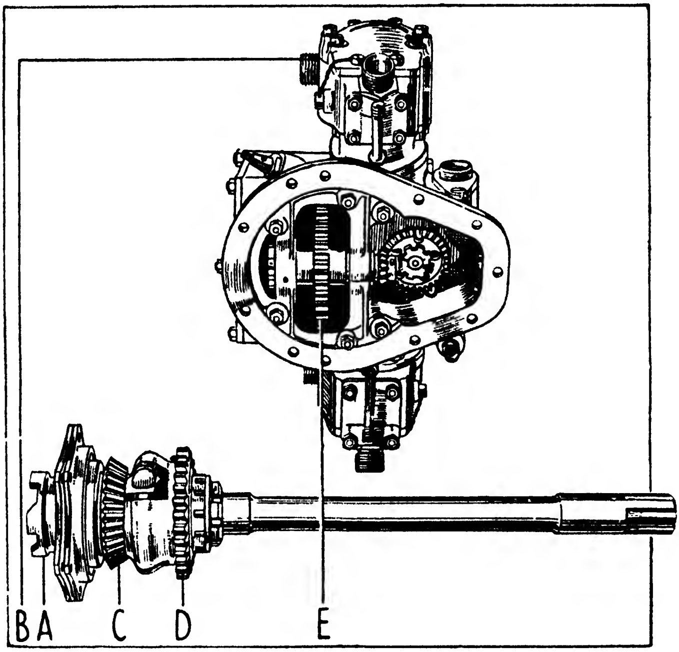

Fig. 14.—The auxiliary drives box and rear drive shaft. "A" the starter dog; "B" petrol outlet from pump; "C" magneto driving bevel; "D" auxiliary drive gear; "E" auxiliary drives box driven gear.

It will perhaps be easier to follow the way in which power is transmitted from the crankshaft to the geared fan of the supercharger after studying the method of assembly, which is as follows :—

It is assumed that the fan layshaft has already been fitted and secured to the diaphragm plate. The first operation is to fit the clutch pads into the gear housing. Each is numbered and the pads must be fitted in numerical order from 1 to 6 and with the face, on which the shoulder is machined, towards the front. Clutch pads are manufactured in sets and are carefully weighed, balanced, and ground to suit the housing to which they are to be fitted. Pads and housings must not be interchanged.

Fit the pinion and large bronze bush over the hub of the gear, engaging the teeth on the pinion with the slots in the clutch pads.

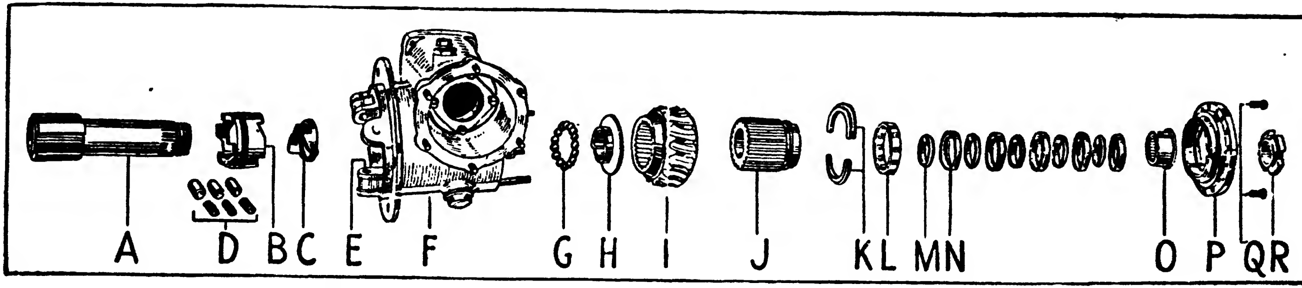

Fig. 15.—The hand/electric starter worm wheel and clutch shaft assembly.

A. Starter driving shaft.
B. Hand starter jaw.
C. Hand starter jaw engaging dog.
D. Starter jaw stops.
E. Starter jaw stop and bosses.
F. Starter casing.
G. Bearing balls (15).
H. Bearing inner race.
I. Hand starter worm wheel.
J. Worm wheel centre.
K. Split collar for worm wheel.
L. Roller bearing.
M. 5 Clutch rings (male).
N. 5 Clutch rings (female).
O. Locking sleeve.
P. Starter casing cover.
Q. Starter casing cover screws.
R. Driving shaft nut.

Tap the ball race into the sleeve followed by the distance piece and secure with a circlip.

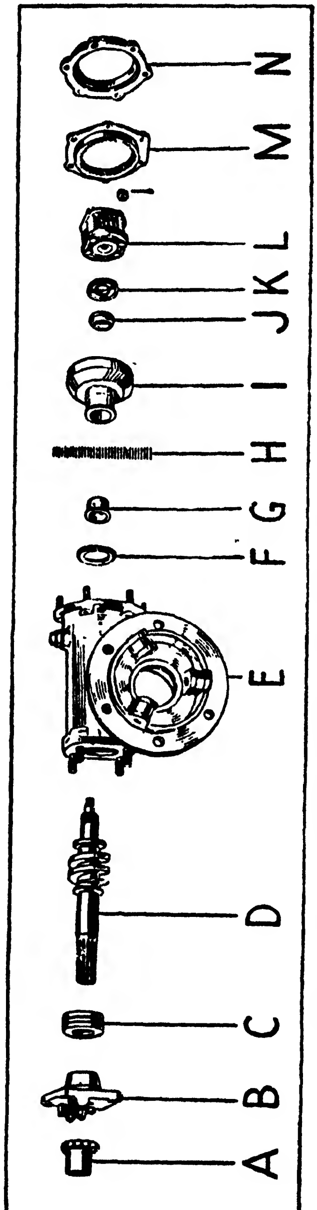

Fig. 16.—The hand/electric starter. The worm shaft and reduction gear assembly.

A. Ratchet gear.
B. Ratchet pawl assembly.
C. Thrust race.
D. Worm shaft.
E. Starter casing.
F. Thrust pad.
G. Worm shaft bush.
H. Needle rollers (34).
I. Internal gear. and roller race.
J. Worm shaft nut.
K. Thrust distance plate.
L. Reduction gear.
M. Stationary gear.
N. End cover.

The sleeve is now fitted through the gear hub from the rear and is secured by a nut and split pin at the front end. Fit the rollers to the inner race on the fan layshaft and tap the clutch gear assembly home. It will now be seen that the forward half of the pinion is in mesh with the crankshaft rear gear while the teeth on the rear half are engaged with the notches out in the clutch pads. Therefore the power is transmitted from the crankshaft rear gear to the fan layshaft pinion, thence through the six clutch pads to the fan layshaft gear, and from this to the fan driving gear. This arrangement provides a gear ratio which allows the geared fan to be driven at 6·52 times crankshaft speed.

The induction case is separated from the crankcase by the diaphragm plate, already described, and houses the supercharger geared fan.

Carefully designed diffuser vanes, machined on the forward face of the induction casing rear cover, surround the fan and increase the efficiency of the supercharger.

The rear driving shaft which transmits the power to the magnetos and auxiliary drives passes through the hollow fan spindle and revolves at the same speed as the crankshaft and is driven through a splined coupling as previously described.

A bevel gear near the rear end of the shaft operating in conjunction with a spring drive coupling, similar to that used on the rear end of the crankshaft, but naturally of smaller dimensions, is engaged with the two bevel gears, one of which is fitted to each of the magneto drives. These drives are housed in the induction casing rear cover and are each secured by means of two countersunk set screws, a locating dowel being fitted in the cover and a corresponding hole being drilled in the fixing flange to ensure correct fitting. A fine adjustment coupling is interposed between the drives and magnetos and this allows very exact timing to be obtained. The magnetos themselves are secured by three nuts and studs and are driven at $\frac{7}{8}$ crankshaft speed.

Returning to the rear drive shaft, it will be observed that it is carried in two bearings, a ball bearing at the rear and a roller bearing in front of the spur gear. The spur gear just mentioned is keyed to the shaft and secured by a locknut and tab washer. This is known as the auxiliary driving gear and transmits power to another spur gear on the horizontal intermediate shaft in the auxiliary drives box which is mounted on the top of the rear cover.

The intermediate shaft is carried in a bracket which is secured to webs in the box by six studs, nuts and split pins and keyed to its forward end is a small bevel pinion. This engages with a bevel gear on the end of the vertical oil pump driving shaft, the backlash between the two bevels being adjustable by the insertion of shims.

A worm gear on the oil pump driving shaft drives the oil pump driven-shaft which is horizontally fitted in the box and this shaft drives the auxiliary box scavenge pump fitted to the starboard side of the box, and the engine speed indicator drive situated on the port side. The fuel pump camshaft is located vertically and parallel to the oil pump driving shaft and is driven by means of a spur gear keyed to the latter shaft.

The starting mechanism, of patented design, is enclosed in a casing mounted on the rear cover and bolted to the rear face of the rear drive shaft rear bearing housing. Starting may be effected either by hand by

means of a cranked handle, with a 16 : 1 reduction ratio, or through the medium of an electric motor working through an epicyclic reduction gear. In each case the drive is taken through a worm and worm wheel gear and a series of phosphor bronze cone type friction clutches. This slipping clutch device is included in the assembly to avoid risk of damage or injury in the event of a backfire.

A shaft carrying external splines protrudes from the starter casing on the port side. The bore of the starting handle end is internally splined to engage with the protruding shaft which is integral with the starter worm-shaft. On the other end of the worm shaft the reduction gear (656 : 1) for the electric motor drive is mounted. Power is transmitted through the worm shaft to the clutch cones and worm wheel and thence to the starter jaw, which is so designed as to be thrown out of engagement as soon as the engine starts. Briefly, the method of assembly is as follows and if this is studied in conjunction with the appropriate illustrations, it will help to make clear the working of the starter :—

The worm shaft is assembled with its ball race on the splined end followed by the pawl assembly and the ratchet which is secured to the shaft by a pin peaned over at both ends. Fit the thrust pad and brass bush to the other end of the shaft and insert the assembly in the casing, securing it with nuts and spring washers. Assemble the roller race on the starboard end of the worm shaft (34 needle rollers), fit the revolving internal gear to the shaft and secure it with the bronze cone nut and spring ring, the loose end of the ring to trail in the direction of rotation of the shaft. The thrust distance plate carrying four steel balls is next fitted, followed by the planet gears in their carrier. This unit is secured by a nut. Now the fixed internal gear can be fitted.

The worm wheel shaft is the next item to be assembled and the first operation is to fit the worm wheel on its splined hub centre and secure it with its split locking ring. The ten clutch cones are now assembled in the hub centre, starting with a plain female ring followed by split male and female rings alternately and finishing with a plain male ring.

Fit the fifteen balls to the outer race in the hand starter body, fit the inner race and follow it by the assembled hub centre. The starter casing cover must now be fitted and secured by two screws to retain the assembly in position when the unit is turned over.

The three starter jaw plungers and springs are now to be fitted in their housings at the forward end of the shaft followed by the engaging dog. Through the forward end of the casing insert the assembled shaft and fit the roller race on the hub. Fit the internally splined locking sleeve and fit and screw up the clutch adjusting nut.

A generator driving unit is bolted to the rear face of the hand/electric starter. This is driven by a shaft which passes through the worm wheel shaft of the starter unit. The forward end of this shaft is externally splined to engage with internal splines cut in the bore of the rear end of the auxiliary drive shaft.

On the rear end of the generator driving shaft a bevel gear is fitted and secured by key, nut, and split pin. This bevel is in engagement with a similar bevel gear on the end of the driven shaft, the correct backlash between the two bevels being obtained by the insertion of suitable shims. The generator is driven at 2½ times crankshaft speed.

2

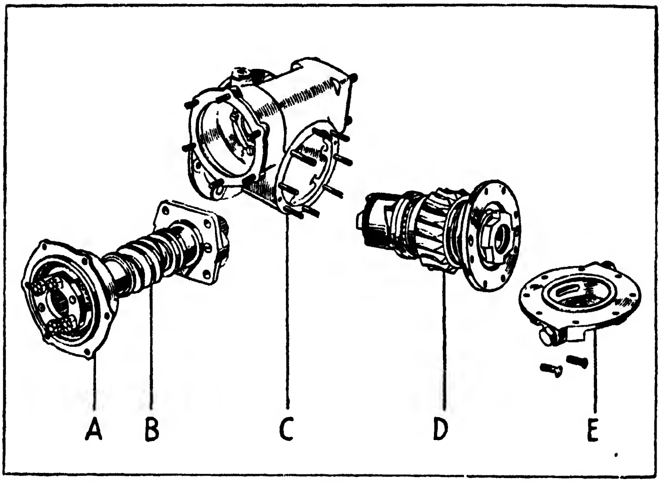

Fig. 17.—The hand/electric starter partly assembled.
" A " reduction gear housing ; " B " worm shaft ; " C " worm wheel bearing housing. " D " worm wheel and clutch shaft ; " E " cover for use without electric starter motor.

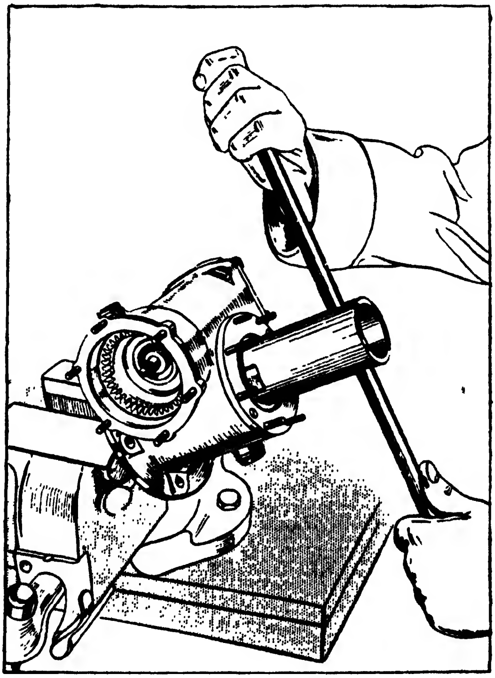

Fig. 18.—Fitting the hand starter clutch adjusting nut.

The carburettor, fitted to the rear of the engine, supplies the mixture through an oil jacketted heater box and rear cover to the centre of the geared fan, whence it is driven to the cylinders through separate induction pipes. Flexible Dermatine packing glands in the induction casing ends and at the valve ports, provide the induction pipes with gas-tight joints. The carburettor contains an override enrichment device which, in conjunction with the variable datum boost control, enriches the mixture sufficiently to prevent detonation during take-off at sea level. Provision is made on the carburettor for a two-stage automatic mixture control which reduces operation of the mixture lever to three positions—override, automatic rich and automatic weak.

LUBRICATION SYSTEM.

Lubrication is of the dry sump type, and is shown in the general diagram, Fig. 19 (Folder). The pump unit, mounted in an accessible position under the front cover, and driven by a dished bevel gear bolted to the front face of the cam drum carrier, incorporates a pressure and scavenge pump.

The pressure pump draws oil from the tank, forces it down the eleven multi-cell discs of the pressure filter in the pump body and delivers it to a chamber fitted with a relief valve in the bottom of the pump unit. Each filtering element consists of two sheets of gauze. The relief valve by-passes oil in excess of 65 lb. sq. in. through a passage cut in the lower stage of the pump casing to the suction side of the scavenge pump. The pressure filter is so designed that should it become choked it rides back against a spring, allowing unfiltered oil to reach the crankshaft.

The main oil flow is forced up the pressure filter strainer tube, through a passage in the top of the pump unit and up the hollow pump spindle to an annular chamber cast in the front cover. From this chamber pressure oil is forced through four holes in the cam race locknut locking sleeve to two holes drilled radially in the hollow crankshaft.

Two oil retaining scrolls are cut in the exterior of the locking sleeve, which is keyed to the crankshaft ; oil leaking from the front scroll lubricates the crankshaft thrust race. The crankshaft front roller bearing, cam race, cams and tappets are lubricated by oil leaking from the rear scroll, and a similar scroll incorporated on the crankshaft locknut prevents oil escaping from the front cover thrust plate. An oil groove cut in the rear end of the locking sleeve feeds pressure oil to a circular groove and hole in the cam race locknut to assist in the lubrication of the cam ball race. Three holes in the locking sleeve housing and two in the thrust race housing allow surplus oil to return to the crankcase sump.

Pressure oil is forced along the hollow crankshaft through a passage drilled in the front web to the hollow crankpin, where it lubricates the master rod bearing through holes feeding grooves cut at 180° to each other on the crankpin. Holes in the master rod corresponding with holes drilled in the main bearing feed pressure oil to the hollow anchor pins, thus lubricating the auxiliary rod anchor pin bushes.

A hole drilled in the rear web of the crankshaft feeds pressure oil to the crankshaft rear roller bearing and spring drive. Three holes and a groove in the crankshaft rear end feed pressure oil to the fan gear shaft white-metalled bush. Excess oil is drawn off from the last mentioned bush by three passages drilled in the crankshaft rear web, the passages communicating with the crankshaft rear end.

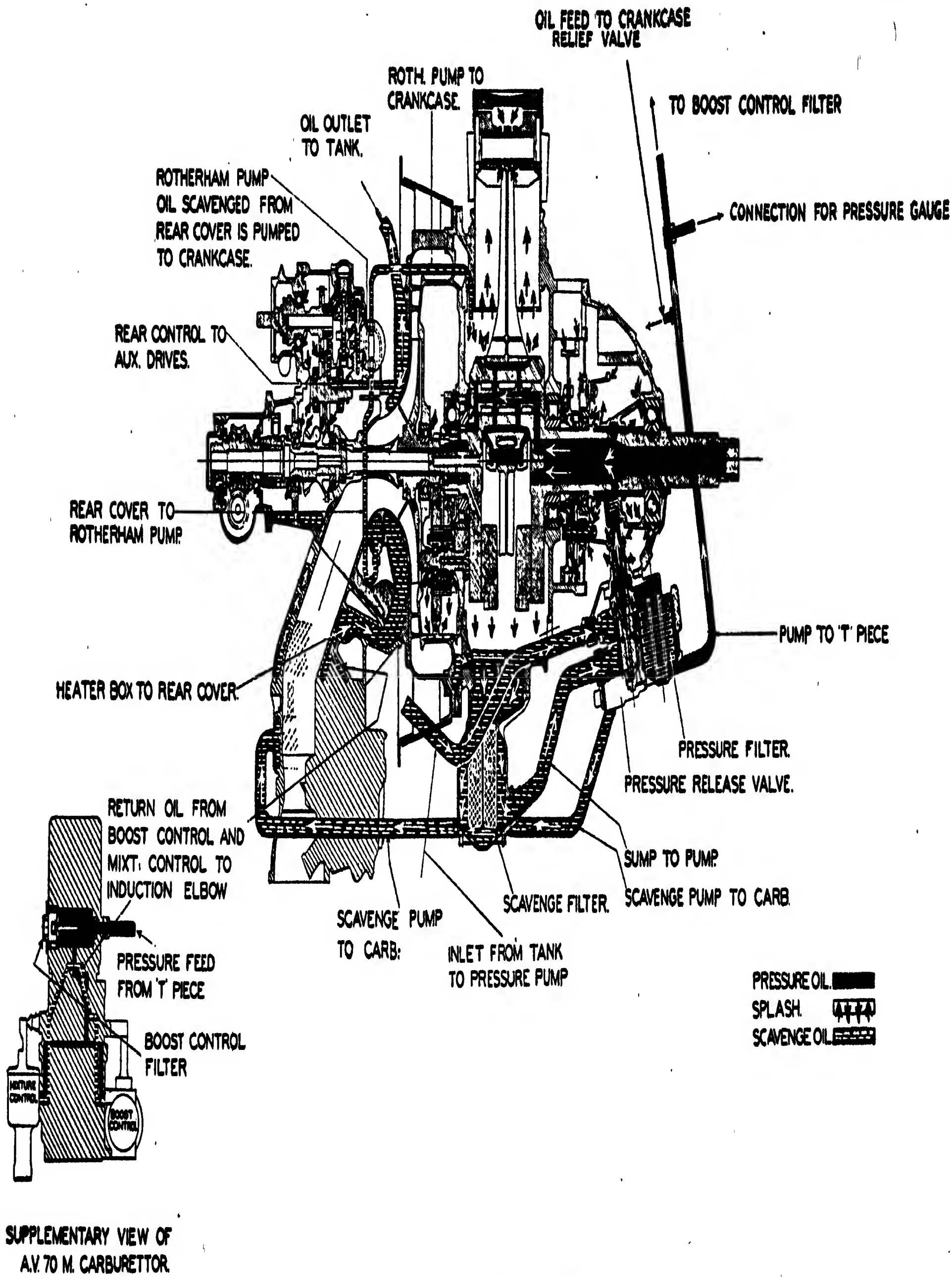

Fig. 19.—Lubrication Diagram for Cheetah IX.

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On emerging into the crankcase the oil is churned into a mist which lubricates cylinder walls, gudgeon pins and bushes and the crankshaft front bearing. The induction fan clutch and driving gears are separated from the crankcase by the diaphragm plate, and an oil trap on the crankcase side at the bottom of the plate feeds oil to the hollow clutch spindle to lubricate fan driving gear, clutch gear and clutch.

Additional splash oil is supplied to the fan and clutch gears through three holes in the face of the diaphragm plate. Used oil drops into the bottom of the induction casing cover where it flows through a hole below the diaphragm plate into the crankcase and thence into the sump.

Two oil scrolls on the induction fan and hub and a bronze oil retainer on the rear drive shaft prevent oil from passing into the induction chamber.

An oil feed valve fitted to an adaptor in the top of the crankcase and connected by an external pipe to the pressure pump ensures a sufficient supply of oil to the crankcase and cylinders under cold starting conditions. A pipe leading from a Tee piece in the above-mentioned pipe line leads to the automatic boost control filter. An adaptor is provided in the boost control oil pipe to take the pressure gauge connection.

Surplus oil is collected in a sump bolted to the bottom of the crankcase. The sump contains a scavenge filter. Oil drawn from the sump by the scavenge pump passes through this filter and is delivered to the carburettor heater jacket, heater box and rear cover, thereby cooling the oil and warming the mixture. An external pipe conveys the scavenge oil back to the tank from a union in the top of the rear cover.

A small pipe connected to the starboard inspection plate on the rear cover feeds scavenge oil to the auxiliary box to lubricate the fuel pump cams, engine speed indicator gear, and magneto bevel gears. Two oil seals, one in the rear drive shaft front roller bearing housing and the other in the rear ball bearing housing, prevent oil from entering the induction system and hand starter. The oil finally collects in the bottom of the magneto bevel drive casing where it is scavenged by a Rotherham pump and returned to the crankcase.

Two breathers situated on top of the front cover act as relief valves in the event of too high a pressure being built up in the engine.

INSTALLATION.

Unpacking and Slinging.—Remove the bolts from the lower ends of the iron lifting straps attached to the sides of the case and lift the top and sides clear of the base. Take care to obtain a straight lift in order to avoid damaging the engine.

Clear away all loose packing material and remove the airscrew hub and oil pipes, which will be found packed separately in the base of the case. If the engine is packed in flying position, remove the carburettor, attach a double sling to the crankcase eyebolts, using a spreader to avoid damaging the fins of the vertical cylinder, unscrew the nuts bolting the engine to the bearer plate and hoist. Remove all felt, paper and traces of foreign matter. Wash the engine down with paraffin, using a stiff brush to remove the rust preventive.

If the engine is packed vertically, unscrew the base plate bolts and hoist it by an eyebolt which is to be screwed on to the end of the crankshaft.

Controls and Connections.—Flush all pipes thoroughly with petrol and, if possible, blow compressed air through them to ensure cleanliness. Clean the unions and nipples.

The spherical ends and cone seatings in pipe joints and unions must be clean and they must seat perfectly to ensure freedom from leakage. If they do not seat properly, lap them in and wash them before fitting.

Inspection of Connections.—Make a number of checks before fitting the engine into the mounting. Check the mounting structure for alignment, face accuracy and burrs, and examine the struts and joints attaching it to the airframe for rigidity and tightness. Any movement here will cause vibration.

Examine the flexible shaft to the engine speed indicator in the cockpit. It should be possible to turn the shaft and its indicator hand from the engine end. Keep the shaft well greased ; by removing one of the slotted collars it is possible to withdraw the inside shaft for examination. Take care when replacing it not to twist the shaft. Keep the squared ends well greased and the small locating collars from binding in the adaptors when tightening, otherwise jerky readings will result.

Electric Starter Motor.—With the engine in flying position, remove the blanking plate from the end of the starter unit and fit the electric motor.

NOTE.—On no account is the hand/electric starter to be turned round its axis to suit different installations. If the starter is so turned there is a danger that oil may enter the electric motor.

Installation of Engine in Aircraft.—Sling the engine into position against the engine bearer in the airframe. Take care not to damage auxil-

iaries, ignition leads, magnetos and oil pipes when guiding the engine into the mounting.

Bolt the engine to the bearer, starting at the top and working downwards. With the top bolts fitted there is less chance of damaging the bearer plate should the crane fail to take the strain. Maintain the weight of the engine on the slings till all nuts are tight. Tighten and split pin the nuts; take care when tightening not to damage or twist the engine bearer.

Carburettor and Throttle Levers.—Clean the carburettor and remove all blanks. Remove the blanking plates from the heater box and induction port. The fitting faces must be clean and free from burrs. Fit the Alcumite washer to the induction flange and fit the carburettor and heater box.

Fit the air intake and washers.

Set the cockpit throttle lever and carburettor butterfly in the closed position and couple the control rod connecting the carburettor to the cockpit.

Connect the mixture control.

A notice should be displayed in the pilot's cockpit saying:— "THROTTLE GATE FOR EMERGENCY ONLY."

The mixture control lever should clear the stop at the closed throttle position so that the throttle may be closed positively.

With the automatic mixture control a special quadrant is fitted in the cockpit with the throttle and mixture control levers interconnected by a series of cams. Three positions are marked on the mixture section of the quadrant which has no gate.

1. Override (fully back).
2. Rich Automatic (midway).
3. Weak Automatic (fully forward).

(1) With the mixture lever in the first position the pointer on the override scale on the port side of the carburettor is to be in the middle of the red segment.

(2) With the mixture lever in the second position the two lines scribed on the mixture cock cover of the carburettor should coincide and the pointer on the override scale must be on the edge of the red segment.

The controls should work smoothly to the full extent of their travel and their movement must not be restricted by the quadrant.

Pipes, Connections and Leads.—Remove all blanks except those for sparking plug and exhaust ports. Keep the blanks for future occasions. Make the following connections:—

OIL.—Main oil feed pipe. Pipe from scavenge union on pump to carburettor. Main oil return pipe from rear cover to tank. Feed pipe to automatic boost control oil filter.

FUEL.—Main pipes from tank to filter and fuel pumps. Pipe from Y piece to carburettor. Pipe from Y piece to pressure gauge. Drain pipes from fuel pumps. Pipe from engine primer pump to primer ring. Drain pipe from air intake.

CONNECTIONS.—Oil thermometers. Driving shaft to engine speed indicator. Oil pressure connection from engine to pressure gauge. Pull wire from slow running cut-out on carburettor to cockpit.

LEADS.—Leads from magnetos to switches. Leads to hand magneto. Leads for hand/electric starter.

BOOST.—Pipe from induction case to boost control. Pipe from induction case to boost gauge.

With switches off make certain that the magneto circuits are earthed.

Carburettor and Fuel Pumps.—The carburettor will function with a head of fuel ranging from 10 ins. and 12 ft.

The fuel pumps will operate with a 10 ft. suction lift.

Fuel System.—If a gravity tank is fitted, check the fuel flow at the carburettor. This flow should be 100% in excess of engine requirements, or 10 gallons per hour more than 20% of engine requirements, whichever is the smaller. The requisite figure for the Cheetah IX. is five pints per minute.

Make sure that the fuel pipes are of adequate diameter and that the cocks in the system are of suitable bore dimensions. In cases of doubt the engine should be run on the ground from an independent fuel supply and the delivery from the pump system noted and compared with the pump delivery figures declared by the makers.

When making this check it is important that the fuel supply pipe should be kept on a level with the carburettor inlet union, in order to maintain the normal working head.

The Boost Gauge.—Since the Cheetah IX. is a moderately supercharged engine, a boost gauge is installed in a conspicuous position in the pilot's cockpit. Two positions of the pointer on the dial are of importance to pilots, and these are indicated by a special quadrant. These positions correspond to " Maximum climb and level boost," which indicates that rated power is being maintained, and " Maximum take-off boost " which indicates the maximum throttle opening that can be given without dangerously over-stressing the engine.

The gauge, connected by a pipe to a union in the top of the induction casing cover, registers the boost pressure on the delivery side of the induction fan. The unions connecting the pressure pipe from the induction casing cover to the boost gauge must be dead tight, since any leakage will cause faulty readings. Avoid acute bends in the pipe.

The gauge should be checked frequently by reference to a reliable standard barometer, and it should read the barometric pressure for the day when the engine is cold. The following table gives the correct readings of the boost gauge for barometric pressures, ranging from 28·9 ins. to 30·94 ins. of mercury.

Gauges which shew a deviation of plus or minus $\frac{1}{8}$ lb. sq. in. from these figures, may be considered defective.

Barometer Reading. (In. of Mercury)	Boost Guage Reading. (lb./sq. in.)
28·9	minus $\frac{1}{2}$
29·15	minus $\frac{3}{8}$
29·41	minus $\frac{1}{4}$
29·66	minus $\frac{1}{8}$
29·92	zero
30·17	plus $\frac{1}{8}$
30·43	plus $\frac{1}{4}$
30·68	plus $\frac{3}{8}$
30·94	plus $\frac{1}{2}$

Airscrew Hub.—Airscrew hubs are stamped when they leave the factory with the number of the engine to which they are to be fitted. It

is very desirable that a hub should always remain fitted to the engine to which it is allocated.

Fit the airscrew hub to the airscrew and tighten the nuts on the bolts progressively all round. Smear engine oil on the splines of the crankshaft and on the faces of the front and rear cones. Slide the rear slotted cone SR.30895 on the crankshaft, making sure that the four recesses on the cone engage with the dogs on the crankshaft locknut.

When fitting front and rear cones, oil them thoroughly to prevent the metal chafing against the crankshaft and front end locknuts. If the rear cone is not well oiled it may tend to stick against the crankshaft locknut.

On examining the crankshaft and the bore of the airscrew hub, a master spline will be observed on each. The lining up of these two splines ensures that the airscrew hub is always fitted in the same position.

The locking device is permanently fitted in the end of the crankshaft. Fit the airscrew and hub to the crankshaft. Place the two halves of the front cone SR.12583 on the flange of the crankshaft hub nut SR.21441, insert the whole in the airscrew hub, screw up the locknut and tighten with the spanner SR.23380. Make sure that the plunger has sprung into the engaged position.

Locking Device.—The airscrew hub locking device embodies a serrated spring loaded plunger which engages with corresponding serrations inside the front end nut. Ensure that the serrations on the plunger are free in the serrations of the airscrew hub nut and that the plunger when pushed right in disengages by about 0.1 in. from the nut. Unless this is the case the hub will not be secure after tightening.

It is absolutely essential when fitting or removing the airscrew to ensure that while turning the airscrew hub nut the locking device is out of engagement. If this is not so and force is used the locking device will be damaged. A projection in the airscrew hub spanner will automatically disengage the locking plunger if sufficient forward pressure is exerted.

When fitting a metal airscrew, ensure that the track is correct and, if adjustments have been made, that the bolts holding the halves of the hub together are dead tight and locked.

Track of Airscrew.—Check the alignment of the airscrew with the machine as follows :—Measure the tip of one blade from some convenient point on the machine, rotate the airscrew till the other blade is at the same point and measure again. The difference between these two measurements should not exceed $\frac{1}{4}$ in. The above tolerance applies to wooden airscrews. Where metal airscrews are employed, the tolerance should not exceed 2 mm.

If satisfactory, lock the tab washers on the hub bolts..

Valve Clearances.—The clearance between the rocker striker bearing and the top of the valve stem should be checked both for inlet and exhaust valves when the piston is approximately at top dead centre on the firing stroke, *i.e.*, with both valves closed.

Valve.	Cold Clearance.	Hot Clearance.
Inlet, ...	0·010 in.	0·010 in.
Exhaust	0·010 in.	0·010 in.

Valve Clearance Gauge, SR.28833.

Adjustment of valve clearances is effected by unscrewing the locknut

and inner nut of the rocker fulcrum pin with the spanner SR.27374, and by turning the squared end of the fulcrum pin with the other end of the same spanner. The fulcrum pin incorporates an eccentric which regulates the clearance. It is essential that the eccentric be on top. If it is down the rocker is too far back on its seating with the result that the push rods are liable to foul their covers. To ensure that the eccentric is on top, adjust the clearance when it is too big by turning the pin TOWARDS the airscrew; when the clearance is too small, turn pin AWAY from the airscrew.

The best method for checking the valve clearances is as follows :—With both valves closed on No. 1 cylinder and the piston approximately at T.D.C. on the firing stroke, adjust the clearances. Turn the crankshaft clockwise until the valves of No. 7 cylinder lying next to it anti-clockwise are closed and adjust the clearances. Repeat the operation for the other cylinders, turning the crankshaft clockwise and checking the cylinders anti-clockwise.

Having adjusted the clearances, apply the grease gun to all the nipples, using Triers grease and pump till grease appears at both sides of the rocker. Remove excess grease. Make sure that all the locknuts are tight. Shut the rocker covers and lock them with the spring clips attached.

Exhaust Collector.—Remove the exhaust port blanks, fit the copper and asbestos washers and threaded adaptors to the exhaust ports. Fit the copper and asbestos washers into the exhaust collector locking rings and the two halves of the exhaust collector to the exhaust port adaptors, screw up the locking rings and secure them with circlips. Insert the copper washer between the two flanges of the collector, fit the bolts and nuts and secure them with split pins.

Flushing Crankcase, Cleaning Sump and Pressure Filters.—Remove the sparking plug blanks and the circlip and locking plate from the crankcase sump. Using the spanner SR.21386, unscrew the oil sump cap, remove, and, if necessary, clean the filter in petrol, and drain the sump. Remove the oil from the cylinders with a syringe.

Open the exhaust valves of the bottom cylinders to release the oil trapped in the combustion chambers. Turn on the oil and, with switches off, rotate the engine, preferably by Hucks starter to ensure a free circulation to clear any old oil from the crankcase and cylinders and to register an oil pressure on the gauge. Replace the sump filter, screw up the cap and fit the locking plate and circlip.

Pressure Filter.—Remove the circlip and locking plate from the pressure filter cap in the bottom of the pump body. Using spanner SR. 23190, unscrew the cap and remove the filter. Withdraw the filter from cap, taking care not to lose the coil spring. Remove the circlip, washers and spring ring from the top of the strainer tube and slide off the filter gauzes. Clean the gauzes in petrol and replace them on the strainer tube. Fit the plain washer, spring ring, bevelled washer and circlip. Place the coil spring in the recess in the filter cap and fit the large end of the strainer tube over it. Refit the assembly in the pump body, screw up the cap and replace the locking plate and circlip.

NOTE.—Whenever the oil filters have been removed, the crankcase must be primed with oil in accordance with Detail Lubrication Instructions prior to starting the engine.

Plugs and H.T. Leads.—By means of a syringe inserted in the sparking plug holes, spray a little hot oil on to the walls of each cylinder in turn.

Clean the sparking plugs and set the gap (0·012 in.), graphite the threads and screw the plugs in tight. Start the threads carefully in order not to damage the adaptors. Spanner SR.37825.

Connect and secure the H.T. leads. Leads from the starboard magneto are connected to the sparking plugs in the front of the cylinders and leads from the port magneto to the plugs in the rear. Leads from the port magneto have black identification sleeves and the starboard red.

Fuel, Oil and Tanks.—Fill up with an approved grade of oil and fuel. Use suitable filters when filling the tanks and thereby relieve the filters in the installation of unnecessary duty. It must be understood that apart from the oil necessary for each hour of flight there must be sufficient surplus in circulation, as the engine oil pump circulates 4 gallons per minute.

While the engine is running at normal R.P.M. under load, there are about two pints of oil in the crankcase in a state of mist. When filling the tank due allowance must be made for this, for frothing and expansion, and for the oil already in the engine, which will immediately be scavenged back to the tank on starting up.

When the temperature of the day is below normal, *e.g.*, 15°C, the oil should be heated to about 70°C. before being poured into the tank. By so doing, adequate oil pressure will be more quickly obtained on starting up the engine.

The capacity of the oil tank must be such that the oil endurance is at least 50% greater than the fuel endurance under normal conditions.

In the event of the failure of a connecting rod big end bearing, it is essential that all traces of loose bearing metal be removed from the oil system in the aircraft before another engine is installed.

The aircraft must be placed in such a position that the oil tank can be thoroughly drained, flushed with a mixture of 95% paraffin and 5% mineral oil. If any doubt exists as to the efficiency of the drainage and flushing operations the tank should be removed from the aircraft to facilitate the thorough performance of these operations. It is essential to remove all traces of paraffin before refilling with fresh oil.

Priming the Fuel Pumps.—Disconnect the feed pipe from the carburettor. Turn on the fuel and operate one of the pump levers smartly till a flow appears. Turn the airscrew two revolutions and operate the other pump lever till a second flow appears. Turn off the fuel and connect up the pipe.

Checking the Fuel Pumps.—With the engine running at 1000 R.P.M. hold the port fuel pump priming lever out for three or four minutes. By holding the priming lever out the diaphragm will not work and the starboard pump can be checked. Repeat this procedure with the starboard pump to check the one to port.

DETAIL LUBRICATION INSTRUCTIONS.

Immediately Before Starting a New or Overhauled Engine.

Crankshaft.—Remove the cap nut from the oil pressure adaptor on the oil pump. Couple a hand pump to the union and pump in half a gallon of warm oil (D.T.D.109) up to a pressure of at least 25 lbs. sq. in. while

the engine is being turned by hand starter. Replace the cap nut and lock it with wire.

Crankcase.—Remove the plug from the top of the crankcase and pour in half a gallon of approved engine oil. Replace the plug.

Magneto Drive Chamber. Remove the plug from the port side of the rear cover. Pour in three quarters of a pint of approved engine oil. Replace the plug.

Hand/Electric Starter.—Unscrew the plugs in the top and bottom of the starter unit, pour in oil till it overflows from the bottom hole. Wait until the oil stops overflowing before replacing the plugs.

Generator Drive.—Unscrew the top and bottom plugs and pour in engine oil till it overflows at the bottom hole. Replace the plugs.

Rocker Bearings.—Lubricate with Triers grease at the nipple on top of the rocker. Wipe away surplus grease.

Magnetos.—See instruction plate on magnetos.

Final Inspection.—With switches off and throttle wide open, note the following points :—

(1) Examine the engine controls and make sure that they function in the prescribed manner. Lubricate all joints and links.

(2) Check over the electrical leads to the cockpit and make sure that the ignition is switched OFF after making this check.

(3) Check the make and break contacts for correct gap—0.011½ in. to 0.013 in. Reset them if necessary.

(4) Examine the airscrew hub for security and ensure that the nuts are tight and locked.

(5) Fit the cowling, taking care that there is sufficient clearance between the trailing edge of the cowling and the lower half of the hot air intake, otherwise damage may occur.

(6) Make sure that the cowling attachments are dead tight and securely locked. This is most important.

(7) Examine the engine mounting bolts for security and see that they are properly split-pinned.

(8) Remove all rags and loose tools from the engine and aircraft.

The engine is now ready to be started up.

Starting.—When running up the engine after installation, or whenever making power or boost checks, head the aircraft into wind well away from the shelter of hangars and sheds.

Turn the engine ten times by hand starter with oil on and switches and petrol off.

Turn on the fuel. Make sure that the cocks are held positively in the open position.

Open the throttle to about one-eighth of its travel and see that all switches are OFF.

See that the mixture control is in the rich automatic position.

Hand Starting.—Starting from cold, give six to ten strokes of the hand primer pump, turning the engine during this operation by the hand starter. Switch on the hand starting magneto, continue turning the hand starter and operate the hand magneto; as soon as the engine starts firing switch on the main magnetos. When the engine starts the hand starter is automatically disengaged.

NOTE.—On no account switch on the main magnetos before the engine

fires on the hand magneto. These magnetos are timed early and, owing to the slow rate of turning by the hand starter, a backfire may follow if they are switched on before the engine fires.

If conditions are very cold, give the primer pump two extra strokes as the engine fires. This is entirely a matter of judgment and conditions.

Should the engine fail to start, proceed as before preferably without further use of the primer. Avoid overpriming. If the engine is warm, two strokes of the primer should be sufficient.

Hand Starter Clutch Adjustment.—If the clutch on the hand starter shews signs of slipping, remove the blanking plugs on each side of the forward end of the generator drive casing, and insert two special bolts SR.26634 which, when screwed in, bear against flats on the clutch end nut. It is most important that these bolts should enter easily. If they fail to do so, ease the starting handle shaft gently round until this can be done. By turning the starter worm shaft slowly by hand, the nut can be tightened as required. Unscrew the bolts and replace the plugs.

The adjusting nut should only be tightened enough to enable the clutch to turn the engine over compression. The degree of adjustment can be tested by removing the bolts and by trying to turn the engine. If this is possible no further tightening is necessary.

It is essential that the clearance between the jaw of the starter and rear drive shaft be 0·050 in. with the jaws disengaged. This clearance is adjusted by means of shims between the starter and the casing to which it is fitted.

Hand/Electric Starter.—Starting from cold, give ten strokes of the hand primer, turning the engine over during this operation, either by hand or by depressing the outer ring of the starter switch. Switch on the coil which takes the place of the hand magneto and depress the inner knob and outer ring of the starter switch. As soon as the engine starts firing, switch on the main magnetos.

If conditions are very cold, work the throttle smartly two or three times as the engine starts firing.

For quick starting with the engine hot, work the throttle two or three times open and shut with the starter switch on. This has the effect of injecting a fuel spray up the chokes by means of the accelerator pump. Avoid overpriming. Turn the primer off after use.

A safety switch is provided in the circuit to prevent the coil being switched on by accident. The system is so arranged that in the event of the motor failing or the battery running low, the coil only can be switched on by placing two fingers under the outer ring to keep it out and by pressing the inner knob with the thumb. Provided the coil switch is on, the depression of the coil button on the starting switch will still provide the necessary spark for ignition while the starter is being turned by hand. Only a very low amperage is necessary for this purpose.

Batteries and Connections.—If the aircraft W/T battery is to be used for starting, it must have a capacity of at least 50 ampere hours and must be sufficiently strong to withstand a discharge of 75 amperes for 30 seconds. If the engine fails to start after 30 seconds, carry out the usual investigation for the failure of an engine to start as described further on. Under no circumstances should the motor be run for more than 30 seconds at a stretch without an interval of three or four minutes.

The aerodrome service battery should be used whenever possible in order to save the W/T battery.

When using an external service battery a plug and socket are provided. The plug which is connected to the external battery is inserted into the holes in the socket cover, turned in a clockwise direction till the prongs engage with the holes in the socket body and finally pushed home. This automatically disconnects the aircraft battery.

If an external battery has been used and the plug has been left in the socket, it will be impossible to use the aircraft battery until the plug is withdrawn.

Generator.—This should not be driven unless the system is completely wired. Ample provision must be made for cooling.

Safety Precautions.—As a safeguard for persons working on or near the engine, do not touch the airscrew except when necessary. If by any chance a switch is left on and the airscrew is moved, the engine may start even when cold.

Turn the primer cock off after use.

Preliminary Run.—Having started the engine, run it at 600 R.P.M. for a few seconds and watch the oil pressure. At first a high pressure will be built up due to the cold condition of the engine and the increased viscosity of the oil. As the engine warms up the oil pressure will gradually fall to a steady figure which should not be less than 35 lb./sq. in.

If there is any tendency for the oil pressure to fall below 35 lbs./sq. in. when the oil is thoroughly warm, examine the joints in the system for possible air leaks and rectify them. If the pressure still remains below 35 lbs./sq. in., remove the relief valve which is situated in the bottom of the pump casing opposite the oil pressure union, and add a shim or shims between the spring and the relief valve until the requisite figure is obtained.

As soon as the oil pressure shows a steady reading, run the engine at the speed which suits it best between the limits of 800 and 1000 R.P.M. till the oil circulation is well established and a rise of 10°C. is obtained above the initial cold starting temperature or for not more than five minutes at this speed. Operate the mixture control in accordance with instructions already given to prime the unit with oil. When this condition is fulfilled, accelerate up to 1200 R.P.M., then to 1400 R.P.M. with a ten second pause at each stage.

Note the fuel pressure and check the ignition switches. Accelerate steadily up to full throttle, avoiding instrument surge. Check rated boost, and, with override in, check maximum take-off boost and R.P.M. which should attain within 50 R.P.M. of take-off speed. Return the mixture control to the automatic rich position. Shut down steadily and check the slow running, which should be less than 400 R.P.M.

NOTE.—While warming up, the oil cooler should be switched out of circulation, where this is possible, or protected from the influence of the slip stream.

General.—The above paragraphs refer to the preliminary run only; this detailed procedure is not necessary on subsequent runs.

Should there be any excessive vibration while running up shut down the engine immediately and examine the airscrew hub and engine mounting carefully. Flight should not be undertaken until the cause has been found and rectified.

Full load periods on the ground must be as brief as possible, since the engine is not adequately cooled until in flight.

To test the magnetos switch off each one alternately and note the drop in R.P.M. Should the drop exceed 50 R.P.M., examine the ignition system for faulty plugs, incorrect make and break contact settings and faulty leads.

BOOST.

Maximum Climbing and Level Boost.—The maximum climbing boost pressure is plus ½ lb./sq. in. This is the boost pressure approved for the engine for climbing from 1000 ft. to rated altitude and for "all-out" level flight (of not more than 5 minutes duration).

Take-Off Boost.—This is the boost pressure permitted for take-off and in the case of this engine is plus 2½ lbs./sq. in. This boost is obtained at sea level with the override on the automatic boost control in operation and the cockpit throttle lever fully open. Above 1000 ft. the override must not be left in operation during the climb.

Maximum Cruising Boost.—This is the approved boost pressure for continuous cruising and in this engine it is minus ¼ lb./sq. in. This boost pressure must not be exceeded for periods of more than five minutes duration except for climbing and taking off as indicated above. When cruising, observation of the boost gauge is necessary to ensure that this boost pressure is not exceeded.

Automatic Boost Control (Variable Datum Type).—To relieve the pilot of the need of watching the boost gauge when taking off, climbing and flying "all-out" in level flight, to prevent over-boosting of the engine, a device is fitted to the carburettor and connected to the throttle linkwork in such a manner that it automatically controls the opening of the carburettor throttle to maintain the boost pressure within the permitted limits. This device is known as the automatic boost control and it may be set by the pilot to give one of two conditions of maximum boost, *i.e.*, either maximum climbing boost or maximum take-off boost. The variable datum device which is fitted to the automatic boost control varies directly with the movement of the cockpit throttle lever the datum or re-action point of the aneroid of the automatic boost control within the range of boost pressure over which the automatic control operates. The purpose of the device is to ensure a direct response of the carburettor throttle to movement of the cockpit throttle lever.

The automatic boost control consists of an aneroid, similar to those used in aneroid barometers, which is enclosed in a chamber. A threaded rod is attached to one end of the aneroids and over this a sleeve is screwed, the sleeve being adjustable on the rod. The sleeve is actuated by a cam which is connected by suitable levers to the throttle control shaft. The other end of the aneroid is attached to a piston valve. Pressure from the induction chamber of the engine enters the boost control chamber via a calibrated sharp-edged orifice and acts on the aneroid, which in turn moves the piston valve. Movement of the piston valve opens and closes ports through which pressure oil from the engine passes to the piston of a small servo motor, forcing the piston up or down according to the position of the piston valve. The piston of the servo motor is coupled to a toggle

mechanism, which interconnects the pilot's throttle lever with the carburettor throttle lever.

In order to obtain increased power for take-off, and climb the carburettor is fitted with an override device which not only allows the independent use of maximum permissible boost, but also enriches the mixture sufficiently to prevent detonation.

The override device is actuated by the mixture control lever in the cockpit.

When the mixture control lever is moved into the override position, two operations are carried out in the override device. A valve opens, bringing a jet into action which enriches the carburettor mixture by about 12 per cent. and at the same time a second valve opens which connects the boost control to the suction side of the induction system by a duct leading from a venturi in the carburettor to an opening in the induction elbow.

The maximum take-off boost setting is fixed by the engine manufacturers and is regulated by the relative sizes of the calibrated and venturi orifices in the aneroid chamber.

With the mixture control lever in the automatic rich position, that is when the override is closed and the throttle lever fully forward, the boost control functions normally, maintaining the throttle opening at climbing boost according to atmospheric height. With the mixture control lever in override, the pressure acting on the aneroid is relieved by a pre-determined amount due to the introduction of an air bleed through the venturi. This allows the aneroid to extend and a new setting is established which, in conjunction with piston valve, servo motor, and linkage opens the throttle more to give higher power.

A sealed gate is provided in the cockpit throttle quadrant with this type of control, the position of the throttle lever at the gate giving maximum climbing boost. As the throttle lever is closed the variable datum device cam alters the position of the datum of the aneroid, and brings about the required variation in boost pressure.

Movement of the throttle lever through the gate is only for emergency since boost pressures in excess of maximum climbing or " all-out " level boost are not allowed in level flight or in the dive.

Adjustment of Automatic Boost Control.—The engine is fitted at the works with the carburettor and boost control linkage correctly set. The aneroid is adjusted so that with the cockpit throttle lever fully open and the engine on the ground, maximum climbing boost is shewn on the boost gauge (override closed).

If the automatic boost control requires adjusting for maximum climbing boost, proceed in the following manner. With the engine stopped, place the throttle lever in the fully open position against its stop. Pull the servo motor piston to the bottom of its stroke and adjust the connecting rod or toggle links to suit these centres. The setting of the control to maintain a definite boost or induction chamber pressure is carried out by adjusting the aneroid screw which passes through the sleeve at the end of the aneroid chamber.

Under normal conditions at maximum climbing boost the ports of the valve should be in the mid position, that is, both ports closed. Screwing the valve in will increase the boost pressure, whilst screwing it out will

decrease the boost pressure maintained by the control. An eighth of a turn in either direction should be sufficient to produce the required effect.

The aneroid adjustment must not be used for obtaining maximum take-off boost. The override device whereby this is obtained, consists of a calibrated orifice in the aneroid chamber connected by a pipe to the pressure side of the induction system and of a venturi located inside the carburettor connected to a valve operated by the mixture control. The other end of the valve leads into the induction elbow on the suction side of the induction system. On opening the valve, pressure on the aneroid is relieved because, as the venturi is larger than the calibrated orifice, it tends to withdraw more air from the chamber than enters by the orifice.

To increase maximum take-off boost, decrease the size of the calibrated orifice and to decrease maximum take-off boost, increase the orifice. *The venturi must not be altered.*

The servo motor piston has a 1·5 mm. hole drilled through it to allow the oil to flow and to prevent surging. An adjustable stop for the piston, fitted through the top of the cylinder, is set before the carburettor leaves the works. If for any reason such as failure of oil pressure, the boost control goes out of action, the piston cannot go further down than the stop, and this allows the pilot to obtain a reasonable throttle opening with his lever.

Automatic Mixture Control.—The automatic mixture control has certain features in common with the automatic boost control in that the device comprises an aneroid-controlled servo piston which is actuated by the oil pressure of the circulatory system of the engine. In the case of the mixture control, however, the aneroid chamber is subject to atmospheric pressure instead of boost pressure and is, therefore, affected by the change of atmospheric pressure brought about by change in altitude. The servo piston is linked up to the mixture control cock on the carburettor and thereby brings about the necessary correction for the effect of atmospheric density upon the carburettor characteristics.

After Preliminary Run.—After the preliminary run on a new or overhauled engine, it is advisable to shut down and examine it.

NOTE A.—Stop the engine by turning off the fuel and then switching off the engine at the first signs of irregular firing, opening the throttle wide at the same time. This period of slow running will prevent pre-ignition and allow the cylinders and working parts to cool. By opening the throttle wide when switching off, cold air will be drawn into the cylinders, thus tending to retain the oil film on the walls and minimising the danger of drying up when the engine is next started. Furthermore, the engine will be more sensitive to priming.

NOTE B.—When investigating the engine see that the switches are off and the throttle wide open.

(1) There should be no oil or fuel leaks; all joints, connections and nuts should be tight, particularly the induction and carburettor joints, which will cause irregular boost readings if not absolutely air tight.

(2) The cylinders should be fairly hot and the barrel and head locking rings should be tight under these conditions. Should the head locking rings by any chance work loose tighten them (right-hand thread) with the dowel headed spanner. Use the barrel locking ring spanner if the barrel rings are loose.

It may be noted here that a sudden rise or fall in engine temperature, due to careless running up or shutting down, is to be avoided, especially with new engines.

(3) The airscrew hub should be tight.

(4) The crankcase and front cover should be felt by hand and the temperature should be reasonable.

(5) Inspect all oil and fuel filters in the system carefully and clean them.

(6) Drain the lubrication system and refill the tank with fresh oil This refers to the preliminary run after initial installation and not to subsequent running up. If traces of dirt are found in the oil filters, the complete oil system should be thoroughly flushed with a mixture of 95% paraffin and 5% mineral oil. Take care to remove all traces of paraffin before refilling with fresh oil.

(7) Check the valve clearances with the engine cold.

Failure to Start.

(1) Incorrect throttle setting.

(2) Lack of fuel or the presence of water in the carburettor. Investigate pipe lines, cocks and filters for vapour locks, air leaks and accumulation of dirt and water.

(3) Insufficient or excessive priming.

(4) Defective ignition due to: faulty H.T. leads; faulty, oiled up or incorrectly set sparking plug electrode gaps; defective switches; fouled or incorrectly set make and break contacts; moisture or dirt between the segments of the distributor.

Clean the fouled plugs and re-set the gaps. Keep the make and break contacts free from oil, which will carbonise and prevent contact. Remove any pitting and polish in accordance with existing instructions. If petrol is used for cleaning the contact breaker, make sure that the parts are thoroughly dry before re-assembling.

NOTE.—If the engine has been stored in a damp place or has been exposed in the open for a lengthy period of inactivity, lay the magnetos in a warm place and dry them off slowly. If this is not possible, clean away all moisture thoroughly from the distributor with a clean dry rag.

When investigating ignition trouble, remember that the port magneto is wired to the sparking plugs in the back of the cylinders and the starboard magneto to those in the front.

(5) Insufficient fuel head, sticking float or needle valve or choked jet.

(6) Faulty hand starter magneto connections.

(7) Faulty coil or blown fuse.

Faulty Running.—The investigation into faulty running may be considered under the following headings:—

(A) Lack of Power. (C) Low Oil Pressure.
(B) Vibration. (D) Miscellaneous.

A—LACK OF POWER.

(1) Bad distribution, due to weak or rich mixture. A weak mixture may be due to a choked jet, a stuck up float, or a faulty joint in the induction system. A rich mixture may be due to a stuck up needle valve, a faulty needle valve seat or to a worn float fulcrum pin.

To investigate distribution, run the engine in the dark with stub exhaust pipes. The size, colour and condition of the flames afford a reliable guide to the offending cylinders. A long, decidedly blue flame, with a tendency to be ragged, denotes a rich mixture; a bunsen type of flame clearly defined denotes a normal mixture; while a weak mixture results in the latter flame turning a narrow, transparent, dull grey-green. The flames from all cylinders should be of approximately the same length to denote good distribution.

Carburettors are supplied normally tuned. This setting will be found satisfactory for general use and should not be altered.

(2) Leaks in the joints of the induction system.

(3) Incorrect fuel, causing detonation. (Only the specified fuel, D.T.D. 230, octane value 87, is to be used).

(4) High exhaust back pressure due to faulty exhaust collector or tail pipe, if fitted.

(5) Restricted fuel flow or choked fuel filter.

(6) Throttle not opening fully.

B—VIBRATION.

(1) Unsuitable or badly fitted airscrew. This may give too low or too high R.P.M. at full throttle on the ground, on the climb, or in level flight. It may also set up excessive vibration in the engine and aircraft. Check the airscrew with the hub fitted for correct balance and track; ensure the security of the bolts in the airscrew boss and of the locking devices.

(2) Airscrew flutter.

(3) Slack engine mounting structure. Examine the engine bearer bolts, mounting pin joints and riveted joints.

(4) Poor compression. This may be traced to incorrect valve clearances, which should be checked with the engine cold; a valve sticking in its guide, a seized tappet, a badly seating valve, a faulty sparking plug or faulty piston rings.

To test compression try one cylinder at a time by removing a sparking plug from each of the other cylinders and by swinging the airscrew slowly to turn the engine over compression.

(5) Faulty ignition causing irregular firing.

C—LOW OIL PRESSURE.

(1) Unprimed pump and feed pipes.

(2) Air leaks or air locks in the feed pipe lines.

(3) Incorrect relief valve settings, such as might accidentally take place after overhaul, or a stuck relief valve.

(4) Excessive oil pump gear or master rod bearing clearances.

(5) Fouled oil filter.

(6) High oil temperature due to lack of sufficient cooling surfaces.

(7) Low outside temperature causing the oil to congeal in the feed pipes. It should be noted that when operating in temperatures of 10°C. or below, there may be some difficulty in obtaining the required oil pressure when starting up from cold when the engine has been left standing overnight.

If possible, the oil system should be drained after finishing the day's

flying and refilled with hot oil the following morning. If it is impossible to drain the system the crankcase must be primed with hot oil before running the engine and this applies even when oil pressure can be obtained without difficulty on starting up under cold weather conditions. Observance of the foregoing is very important with new engines.

(8) If the oil pressure fluctuates, examine the feed pipe from the tank to the pump. It may be obstructed.

(9) Defective oil pressure gauge.

D—MISCELLANEOUS.

Overheating due to :—

(1) Excessive running at large throttle openings on the ground.
(2) Inferior fuel.
(3) Unsuitable oil.
(4) Insufficient oil supply or too small a volume in circulation.
(5) Weak mixture.
(6) Faulty valve clearances.
(7) Faulty valve or ignition timing.

Flooding Carburettor.—Due to :—

(1) Damaged or stuck float.
(2) Poor needle valve seat or worn float fulcrum pin.

Cold and Hot Weather Operation.—When operating in extremely low temperatures, the main oil feed pipe should be lagged with asbestos, and if it is thought desirable the system should be drained after flight and refilled with hot oil before the next flight.

Conversely, in high temperatures, an oil cooler should be fitted or further elements added to the existing cooler as necessary. A variable hot and cold air intake will greatly assist the engine in both the above cases.

The cold air intake is to be employed for take-off where full power is required or for flight during hot weather. The hot air intake must be used for starting and running up the engine, when flying in cold damp weather, in clouds, rain, snow or ice-forming conditions, and when gliding.

OPERATION.

The following is a summary from the foregoing, of the important points to note and of general procedure to be adopted.

A—Running up the Engine.

(1) Always fill up with an approved grade of fuel and oil and use suitable filters when filling the tanks. Do not expect the small filters included in the installation to do all the work. It must be understood that, apart from the oil necessary for each hour of flight, there must be sufficient surplus in circulation as the oil pressure pump circulates 4 gallons per minute.

(2) Make sure that the oil cock is open and suitably locked in this position. Turn the engine ten times with switches and petrol off.

(3) If the engine has been standing for some time, remove the sparking plugs from the bottom cylinders, thereby draining the oil which may have accumulated in them. Clean the plugs if necessary. Turn on the fuel.

(4) When the engine starts, run it at 600 R.P.M.

(5) As soon as the oil pressure shews a steady reading, which should not be less than 70 lbs. sq. in., run the engine at whichever speed suits it best between 800 and 1000 R.P.M. Continue running at this speed until a rise of 10°C. is obtained above the cold starting temperature.

(6) If the oil pressure fluctuates unduly or falls below 35 lbs. sq. in., shut the engine down and investigate.

(7) Check the magnetos and fuel pressure at 1600 R.P.M.

(8) Open the throttle lever up to the gate and check rated boost (plus $\frac{1}{2}$ lb. sq. in.) and with the mixture lever in override check maximum permissible boost (plus $2\frac{1}{2}$ lbs. sq. in.). Never run at full throttle for more than a few seconds on the ground and do not accelerate or decelerate suddenly.

NOTE.—After running up return the mixture lever to the automatic rich position and leave it there while taxying.

B—In Flight.

Note the following points, especially with a new engine :—

(1) Oil pressure, 60 lbs./sq. in. normal 35 lbs. sq. in. minimum.
(2) Oil temperature, inlet, ... 90°C. maximum ; 70°C. Normal.
(3) *Engine Speed.*

Maximum take-off	2100 R.P.M.
Minimum take-off	1925 R.P.M.
Maximum climbing	2100 R.P.M.
Maximum cruising	2100 R.P.M.
Maximum " all-out " for level flight (5 mins. limitation)	2425 R.P.M.

(4) **Boost.**

Maximum take-off	Plus $2\frac{1}{2}$ lbs. sq. in.
Maximum climbing	Plus $\frac{1}{2}$ lb. sq. in.
Maximum cruising	Minus $\frac{1}{4}$ lb. sq. in.
Maximum " all-out " in level flight	Plus $\frac{1}{2}$ lb. sq. in. (5 mins. limitation

(5) *Take-off and Climbing.* For taking off, the mixture control lever will be placed in the override position and may be retained in this position, which provides maximum take-off boost up to an altitude of 1000 ft. Above 1000 ft. and up to 12,000 ft. the mixture control lever will be kept in the normal rich position or rich automatic position for engines fitted with automatic mixture control, this setting providing the necessary rich mixture for maximum rate of climb up to 12,000 ft. with engines fitted with hand-operated control. The mixture control should be opened until the maximum R.P.M. are obtained and then closed gradually until the R.P.M. begin to drop. At this point maximum mixture strength for maximum power is obtained, which is the desired condition for climbing.

With engines fitted with automatic mixture control the mixture control lever in the cockpit must be kept at rich automatic throughout the climb above 1,000 ft.; the control will automatically correct the mixture strength for the effect of the atmospheric density upon the carburettor characteristics.

(6) *Cruising and Level Flight.* The maximum cruising speed of 2100 R.P.M. and boost pressure of minus $\frac{1}{4}$ lb. sq. in. must not be exceeded for continuous cruising. Speeds in excess of maximum cruising, R.P.M. may not be employed for longer than 5 minutes in level flight and the boost pressure must not exceed plus $\frac{1}{2}$ lb. sq. in. For continuous cruising the boost gauge must be observed to maintain the boost pressure within the required limits. On no account may override be used in level flight or in the dive, unless for any reason it is necessary to use the emergency throttle range, when it is essential that the mixture control lever be put into the override position to prevent detonation.

(7) Weak mixture may only be used when cruising at 2100 R.P.M. or less and at minus 1 lb. sq. in. boost or below. With hand-operated mixture control the mixture is to be weakened by advancing the mixture control lever towards the weak position until a drop of 2 per cent. in R.P.M is registered and then advancing the throttle until the original R.P.M. are restored. With the automatic mixture control weakening of the mixture will be effected by moving the mixture control lever to the weak automatic position. In no circumstances may economical mixture strength (2 per cent. drop in R.P.M.) be used at engine speeds higher than maximum cruising R.P.M. (*i.e.* 2100 R.P.M.) and the boost pressure is not to exceed minus 1 lb. sq. in. after the dropped R.P.M. have been regained by opening the throttle. When cruising at boost pressures over minus 1 lb. sq. in. or when the throttle lever is returned to the slow running position the mixture control lever must be in the normal rich (or rich automatic) position.

NOTE.—Interconnection between the throttle and mixture control levers is provided as a reminder to the pilot that when he desires to use greater boost than economical cruising towards full throttle or to return the throttle lever to the slow-running position, he must first of all assure

himself that the mixture control lever is at automatic normal and not at automatic weak.

(8) When gliding from high altitudes, open the engine up to normal R.P.M. every 1000 ft. long enough to keep it warm.

(9) With an overhauled engine where new cylinders, pistons, a majority of piston rings or new lead bronze bearings have been fitted, or with a new engine, before it is employed for normal service duties a cruising flight of not less than two hours duration should be carried out at 6000 ft. and at an engine speed ranging from 1900 to 2000 R.P.M.

C—Engine not in Use.

The following procedure should be strictly followed if the engine is not to be put into immediate service after an overhaul or is temporarily taken out of service.

On completion of the normal tests for an overhauled engine it must be run for 15 minutes on a non-leaded fuel (D.T.D. 224) and while still hot the engine must be completely drained of all old lubricating oil. Remove the sparking plugs and fit non-return valve blanking plugs. When cold the engine is to be run in by a power turning gear at 400 to 500 R.P.M. with the throttle closed. During this period only clean mineral oil is to be used for lubrication and the scavenge oil run to waste. It is important that running-in speeds on the power rig should not exceed those given above so as to avoid heating of the cylinder barrels and heads.

Remove the non-return blanking plugs and, taking each cylinder in turn, set the piston at the bottom of its stroke and spray into each cylinder 25 cc. of E.G. 174 inhibitor with an air pressure of 65 lbs. sq. in. So as to obtain a uniform coating on the cylinder walls, cylinder heads, and tops of pistons the spraying must be done through each plug hole. In the same way it is essential that the piston should be at the bottom of its stroke, thereby exposing as much of the cylinder wall as possible. Rotating the engine two turns after each spraying will help to ensure that the cylinder walls are well covered.

Spray the exhaust valve stems and necks through the exhaust ports with the valves open and also spray the inside of the exhaust ports with E.G. 174. Treat the inlet and exhaust valve springs and stems in a similar manner, working as much of the mixture into the valve guides as possible. Replace the sparking plug or fit solid dummy plugs. Blank off the exhaust ports and air intake to prevent circulation of air. Thick grease on the joints of the blanking flanges will greatly facilitate this.

The following precautions are to be adopted to prevent external corrosion. The engine is to be thoroughly cleaned and all parts not already protected by enamel, Coslettising or cadmium plating are to be lightly coated with grease or an approved rust preventive. All open unions are to be plugged or covered with the metal dust caps provided or covered with several layers of well-oiled fabric securely tied in position. If the engine is not kept in a zinc-lined air-tight packing case fitted with a perforated receptacle containing calcium chloride, it must be kept in a cool dry place and covered by a dust sheet and the crankshaft rotated by hand about six revolutions every fortnight, leaving the crankshaft at rest in a different position each time.

Before starting the engine carry out detailed lubrication instructions and final inspection. The inhibitor need not be removed from the inside of the cylinders before starting the engine.

PERIODIC INSPECTIONS.

A—Between Flights.

(1) See that the engine switches and fuel cocks are off.

(2) Make a general examination of fuel and oil systems for obvious leaks.

(3) Refill the oil and fuel tanks and secure the caps firmly.

(4) See that all engine panels are secure.

(5) The throttle quadrant incorporates a sealed gate (for use in an emergency only), by which full throttle can be obtained. If the seal is broken, the engine must be inspected before any further flight is undertaken since damage such as burning or cracking of pistons, cylinders, valves, and valve seats may have occurred due to detonation.

B—Daily Inspection.

(1) Check sparking plugs, terminals and H.T. leads for security.

(2) Wipe the engine down if dirty. Cleanliness is emphasized.

(3) Inspect the switches for correct mechanical functioning, and see that they are off.

(4) Inspect the cowling for security.

(5) Check the boost gauge by a reliable standard barometer.

(6) Replenish the fuel and oil tanks.

(7) Examine oil and fuel pipe lines for leaks.

10-Hour Inspection.

(1) Inspect and clean the oil pressure and scavenge filters. Prime the crankcase in accordance with "Detail Lubrication Instructions."

(2) Remove and clean the fuel filters in the main fuel tanks and in the pipe lines; see that the latter are securely locked after replacing them.

(3) Lubricate the engine controls.

(4) Examine the airscrew hub for security and the airscrew for general condition.

(5) Examine the exhaust collector for cracks and burning and the locking nuts for security.

20-Hour Inspection.

(1) Examine the engine mounting bolts for security and make sure that they are properly split pinned.

(2) Examine the cylinder barrel and head locking rings.

(3) Replenish the oil in the hand/electric starter.

(4) Check the contact breaker springs for discolouration.

(5) Check the wiring, switches, and H.T. leads for fraying. Leads must not be stretched tight.

(6) Check the tightness of nuts securing heater box to rear cover, carburettor to heater box, and air intake to carburettor. Make sure that all joint washers are seating properly; failure to do so will introduce air leaks and upset the slow running of the engine.

(7) Remove the main jet, power jet, and enrichment jet from the bottom of the float chamber. Turn on the fuel and flush the system. Drain the aneroid chamber of the boost control.

(8) Clean and inspect the valve gear. Inspect the valve springs for damage. Check the valve clearances. Charge the rocker bearings with grease. Grease the push rod ball ends.

(9) Remove the sparking plugs, and clean them thoroughly. Check and re-set the gaps. Test the plugs in a pressure tester. Reject any that fail to spark at 100 lbs. sq. in.

(10) Replenish the oil in the crankcase gear and generator drive (see Detail Lubrication Instructions).

(11) Test the compression of all cylinders. If a valve blows after checking clearances, it may be distorted or its seating defective.

Gummed up piston rings and faulty sparking plug washers will weaken compression.

(12) Check the make and break contact gaps and test the rocker arm for freedom of operation. An incorrect gap will alter the ignition timing.

(13). Inspect the magneto distributor covers for cracks. Clean the inside of the distributor casings with a clean dry rag. Make sure that the lead connections are secure.

(14) Inspect the controls for backlash and excessive wear in the link pin joints. Check the control settings. Oil the links and joints.

(15) Examine the unions on the boost, fuel and oil pressure pipes for security. Inspect the pipes for cracks and damage.

(16) Remove the airscrew; inspect the bore of the wood for cracks and separating laminations. Examine the splines and cones for wear; inspect the hub bolts and bolt holes for cracks. Oil the cones and replace the airscrew.

(17) Examine the engine mounting structure for damage and security.

(18) Undo the strap on the body of the electric starter motor and remove the cover. Wipe the commutator with a clean dry rag. Inspect the brushes for sticking and the inside of the cover for carbon deposit. Inspect the terminal joints and connections; replace the cover and strap.

(19) Check the operation of the hand turning gear and see that the clutch does not show signs of slipping.

(20) Examine inlet, and exhaust pipe connections and carburettor joints for security.

40-Hour Inspection.

(1) Check the primer for flow and leakage.

(2) Inspect the tappet guide studs and nuts for security.

(3) Drain the oil tank, preferably with engine warm, clean the tank and refill.

(4) Lubricate the magnetos.

(5) If oil is leaking from the top of the push rod cover brackets, renew the bracket leather washers where necessary.

(6) Inspect the boost control oil filter. If only slightly dirty this may be cleaned, but where the engine has been in use on an aerodrome where very sandy or dusty conditions prevail, it may be preferable to scrap the filtering element and fit a new one in its place.

(7) Inspect the earth wires of the main and hand-starting magnetos or coil for security.

(8) Check the operation of the fuel pumps.

120-Hour Inspection.

(1) Clean the oil pump relief valve and the relief valve in the top of the crankcase by rinsing in petrol.

(2) Check the H.T. leads for continuity and serviceability.

(3) Examine the rocker striker bearings for wear.

TOP OVERHAUL.

The following notes cover the main operations carried out during top overhaul and include a number of miscellaneous items necessary for maintenance.

The number of hours after which a top overhaul falls due is not specified since it depends largely on the form of duty on which the engine is engaged.

Remove the airscrew.

Remove the exhaust collector.

Remove the H.T. leads and sparking plugs.

Remove the carburettor and heater box.

It will greatly assist overhaul operations at this stage to remove the engine from the aircraft and place it on a stand.

Disconnect the primer pipe from the banjo pivots on the induction pipes.

Induction Pipes.—Remove the induction port circlips and unscrew the nuts with spanner SR.18371. Unscrew the four 2 B.A. nuts securing the induction pipe flange to the induction case, ease the pipe out of the induction case and remove the dermatine glands. Blank off the induction ports.

Rockers and Push Rods.—Open the rocker covers. Depress the push rod spring with the tool SR.33147 the push rod cover spring with the tool SR.38398, and extract the slotted retaining collar.

With the valve closed, unscrew the outer and inner cone nuts on the rocker fulcrum pin and tap the pin out gently. Lift up the rocker, remove the four shims, put them back on the rocker fulcrum pin and screw on the two nuts. Remove the rocker and push rod in one. Repeat the operation on all other rockers and push rods. Each pair of push rods, rockers, and push rod covers are marked with the number of the cylinder to which they are fitted. They are also marked "E" for exhaust or "I" for inlet, to shew their respective positions.

Push Rod Covers and Brackets.—Compress the push rod cover spring and knock the push rod cover socket out of the rocker cover platform. Remove the four nuts securing the push rod cover bracket, pull the push rod cover bracket towards the cylinder head till it is clear of the studs on the crankcase, and remove the bracket and the two covers in one.

Cylinders.—Cylinders must be removed in the sequence of No. 7 to No. 1 and assembled in the reverse order. No. 1, the master rod cylinder, must be the last off and the first on, otherwise the small ends of the auxiliary rods foul the inner threads of the cylinder adaptors with consequent damage to auxiliary rods and adaptors.

Should it be necessary to remove No. 1 cylinder only, the master rod must be maintained in a central position immediately the cylinder barrel

leaves the crankcase, and the crankshaft may not be turned until the piston and cylinder have been replaced.

Place a short ventilated blank in the rear sparking plug adaptor and spray quarter of a pint of oil into the cylinder to be removed. Fit another blank in the front sparking plug adaptor to prevent the oil from pouring out when the cylinder is unscrewed.

Turn the engine till the piston is roughly at T.D.C. Slacken the cylinder barrel locking rings by unscrewing the set screw, spanner SR.18367, tap the set screw with an aluminium drift to loosen the ring, and unscrew the cylinder out of the crankcase adaptor (right-hand thread).

When unscrewing the cylinder keep the piston moving up and down by oscillating the crankshaft. This prevents circumferential scoring of the cylinder bore.

The piston should be at T.D.C. when removing the cylinder to prevent the rings becoming caught in and damaged by the crankcase adaptor.

It is urgently recommended that the greatest care be exercised when unscrewing the cylinders to prevent their weight resting on the pistons. Note again the importance of oscillating the piston when unscrewing the cylinder.

As each cylinder is removed, insert a crankcase adaptor guard into the adaptor. This will prevent the connecting rods fouling the threads and mouths of the adaptors.

Pistons.—Remove the piston by extracting the gudgeon pin circlip nearest the airscrew shaft. Raise the circlip from its seating, using a pointed instrument, and remove it with a pair of pliers. Push the gudgeon pin out from the other end. If it sticks drive it out with a wooden drift. Remove the piston.

NOTE.—Take care when removing circlips that they do not spring off and disappear. Account for every circlip to ensure that none are lost and and perhaps lodged in the crankcase.

Valves.—Place the cylinder on a large block of wood with a domed end which will enter far enough to keep the valves on their seats., Hold the wooden block vertically in a vice. With the valve spring depressing tool, press down the valve spring retainer ; remove the cotters, keeping them in their original pairs. Withdraw the cylinder from the block, turn the mouth upwards and, after removing a small retaining circlip at the end of the inlet valve stem, withdraw the valves.

Master Rod Bearings.—The bearings can be removed without taking the back off the engine. Remove the split pins from the master rod bolts. Unscrew the nuts of two bolts which are diagonally opposite each other, drive out these bolts with a soft metal drift free from burrs and fit in place of them the two assembly bolts provided in the tool kit. Remove the remaining bolts. If this procedure is not adopted, there is a possibility of producing a wedging action on the bolts which will prevent their removal. To part the master rod from the cap it may be necessary to ease the rod half by lightly tapping the H section of the rod. Account for every split pin removed.

Once the master rod and cap have been split they must be held in such a manner that they are not free to move about and foul the crankpin. Tap the bearing shells free from the halves of the rod and remove them, placing them at once in a special container to prevent damage to the bearing surfaces.

INSPECTION.

Crankpin.—Measure the crankpin and ascertain whether it is within the limits of ovality permitted in the schedule of Fits and Clearances and is not scored or damaged.

Bearings: **(Master Rod)**.—The amount of metal found in the oil filters is a guide to the condition of the bearings.

Check the diametral and lateral dimensions of the lead bronze bearings by the figures in the schedule of Fits and Clearances.

NOTE.—Cleanliness in fitting these bearings is of the utmost importance.

The decision to change or retain main bearings rests with the Chief Technical Officer.

Cylinders.—Remove the carbon from the inside of the cylinder heads, taking care not to damage the valve seatings during this operation.

Inspect the cylinder bores for scoring and check those affected for parallelism and ovality. A polished aluminium disc reflector attached to a rod of suitable length when inserted in the cylinder bore will assist inspection. Cylinders within the limits of "Fits and Clearances" should have their bores lapped to restore the surfaces, using a piston not intended to be fitted to any other engine.

Before entering the piston into the cylinder barrel, place a block in the cylinder head to prevent the piston rings from overlapping the top of the cylinder barrel and becoming jammed.

The lapping medium should be a mixture of Turkey Powder and mineral oil, the mixture of oil and powder forming a thin paste. Wash the cylinder thoroughly with paraffin.

Cylinder bores scored to such an extent that lapping does not restore them are to be reground.

Pistons.—Remove the carbon from the top and inside of the piston crown. By means of thin metal strips carefully remove the piston rings; clean the rings, ring grooves, and oil drain holes. Use only the finest emery cloth soaked in paraffin and on no account emery the piston skirts. Wash the pistons in paraffin.

Check the pistons for ovality and wear; check the rings and ring grooves. Burnish those pistons shewing signs of wear and scoring on the skirt.

Piston Rings.—Place a standard cylinder on its head on the bench, insert the piston with skirt uppermost. Check the gaps of all rings. Ensure that the piston ring is on a parallel bore and square with the skirt of the piston.

Valve Guides.—Check the guides for wear, replacing those worn below the limits. Valve guide extracting tools for inlet and exhaust, and respective assembling tools can be obtained to order.

Valve Seatings.—Inspect the valve seatings and, if distorted, skim them up with the tool ST.23799 with cutter ST.23799-2 for inlet and ST.23798 with cutter ST.23798-2 for exhaust. Limits to which seatings may be cut will be found in the schedule of "Fits and Clearances."

NOTE.—It is most important to remember that the outside diameter of the valve should clear the seating in the cylinder head to prevent the valve hammering and distorting both seat and seating. To avoid this, use the tool ST.23799 with 30° crowning cutter ST.23799-3 for inlet and

ST.23798 with cutter ST.23798-3 for exhaust to back off the top of the valve seating, taking care not to cut beyond the specified limit.

Valves.—Valves are marked for their respective cylinder and port inside the valve head. In case the markings have been obliterated, arrange the valves in such a manner that they can be identified for their respective cylinders on re-assembly.

Valves should not be ground more than is necessary to get a " showing " all round the valve face. Take care not to make the valve hollow faced. If this happens it must be refaced and ground in again.

Use Richford paste thinned with a little oil and grind with a to and fro motion, lifting the valve from its seating from time to time to prevent the latter being scored. Make sure that all traces of grinding compound are washed away from the valve, guide, cylinder head and ports. Wash with paraffin.

Valve Springs.—Check the length and strength of the valve springs by the figures set out in the schedule of " Fits and Clearances." Replace those below worn limits.

NOTE.—Springs may be changed without removing the cylinder from the engine. Turn the engine till the piston of the cylinder to be worked on is at top dead centre, remove the rocker and insert the valve holding tool through the front sparking plug hole in such a manner that it can be screwed up with the cranked end pressing the valve on its seating.

Cotters.—Cotters are marked on the top face to indicate their position ; it is essential to keep them in pairs and to their respective valves. Failure to do so will result in misfits, excessive wear, and even breakage of the valve stems. Remember to number new cotters.

Rockers and Push Rods.—Wash the push rod assembly thoroughly in paraffin and examine the push rods for bends and cracks. Dismantle the rocker from the push rod, examine the needle bearings of the push rod joint and of the rocker striker bearing.

Examine the outer races of the rocker striker bearings for wear and renew if necessary. Examine the centre ball bearings of the rockers and spin them to determine their condition.

Check the strength of the push rod springs by the figures in the schedule of " Fits and Clearances."

H. T. Leads.—Examine the leads carefully, paying particular attention to any points where they have been sharply bent. Check those parts where they have been gripped by brackets and clips. If six adjacent braiding strands are broken, renew the lead.

Pipes.—Wash and clean all pipes ; induction, primer and oil pipes. Inspect them for cracks and damage and pressure test any that are suspected with air in paraffin.

NOTE.—Use only " screw-in " type blanks. Wood, rag or fibre may break up and get lodged in the pipes.

Renewals.—Inspect and renew where necessary the induction packing glands. Fit new copper and asbestos washers to the exhaust ports. Renew all circlips, tab washers and split pins. Renew push rod cover bracket leather washers. Fit a new Alcumite washer between the heater box and the induction port in the rear cover.

IMPORTANT.—Whenever paraffin has been used for cleaning purposes, dry the parts thoroughly to ensure that all traces have been removed.

ASSEMBLING.

IMPORTANT NOTE.—No tab washers, spring rings, circlips or split pins are to be used more than once, fit new ones throughout the assembly.

Anchor Pins.—If the anchor pins have been removed, a good fit must be obtained when re-assembling, if necessary by selective assembly. A light drive fit is required for the plain anchor pins, as excessive interference will cause picking up between the pin and the rod, while any slackness between the two parts is not allowed.

Assembling the Master Rod on the Crankshaft.—Fit the cylinder adaptor guards and turn the crankshaft till the master rod (No. 1 cylinder) is at T.D.C. Smear the crankpin and the bearing liberally with engine oil, and the backs of the shells with a light coating of Keenol grease followed by engine oil.

It will be noticed that the rod is stamped on the side with its serial number and it should be so fitted to the crankshaft that this number faces the starboard side when the engine is fitted in the aircraft. The rod is also stamped with the same number on its forward face and the bearing shells are similarly marked. These last numbers should correspond and should be adjacent to each other when the rod is assembled on the crankshaft. (The term " starboard " where introduced above always applies to the engine as viewed from the cockpit).

Line up with a taper drift. Fit two assembly bolts diagonally and fit the master rod bolts in the two other holes, screwing the nuts on loosely.

Remove the assembly bolts and fit the other two master rod bolts.

Fit the nuts and after verifying that the bolts have entered fully and are kept from turning by the cup-shaped washers being correctly engaged with the shoulder on the rod, screw them up as tight as possible.

They must be tightened diagonally and equally.

When fitting the nuts to the master rod bolts, take care that they are pulled up so that the hole in the bolt end is correctly aligned with one of the castellations in the nut. Check the length of each bolt when the nut is tight by means of the gauge provided. This is a high and low limit gauge of which one side will slip over the bolt while the other side will not. The amount of stretch on the bolt should be 0·012 in. (tolerance plus 0·002 in. minus 0.) If the length of stretch on the bolt is not within these limits, remove the nut, fit another one in its place and check the dimensions again. When a nut is fitted and tightened and the bolt length has been checked and found correct, fit the split pin and lock the nut.

Pistons.—Fit No. 1 piston to the master rod with the number nearest the front of the engine. After oiling the gudgeon pin, fit it into position, fit the front circlip, the rear circlip being already in place. Make sure that the gudgeon pin floats in the piston bosses. Space the ring gaps equally at 180° to each other. Each piston has four rings : one compression ring nearest the crown, two 1° angle rings next and a double scraper ring at the bottom of the skirt. The 1° angle rings are marked TOP and must face the piston crown. Fit one piston at a time, followed by its cylinder. Coat the piston and cylinder bore lightly with Keenol grease followed by engine oil.

NOTE.—The use of Keenol grease prevents circumferential scoring of the cylinder bore by the piston ring area when screwing the cylinder home.

Cylinders.—Set the piston of No. 1 cylinder at T.D.C. and slide the cylinder into place, taking care to ease the piston rings gently into the cylinder. Screw the cylinder into its adaptor while oscillating the piston to prevent circumferential scoring of the bore. Never let the piston take the weight of the cylinder. Proceed with the remaining cylinders in a similar manner.

By means of a straight edge placed across adjacent inlet flanges, line up the cylinders in the order of numbering. Tighten the cylinder barrel locking rings with the spanner SR.18367, using no more force than can be applied with one hand.

On no account use pieces of tubing to increase the power of the spanner, since excessive tightening will distort the cylinders.

NOTE.—It is most important that the lining up of the cylinders is correctly carried out; the design of the valve gear adjustment being of necessity drawn to fine limits, it follows that an incorrectly lined up cylinder will throw the length of the push rod out and upset further adjustment.

Lining up a New Cylinder.—When a new cylinder is to be fitted or when the cylinder adaptor has been disturbed, set the gap of the locking ring between ⅜ in. and ½ in. and screw the cylinder into the adaptor until the ring binds on the lip of the cylinder socket. Note where the centre of the front side of the cylinder comes in relation to the crankcase and mark the latter.

Remove the cylinder and mark the adaptor to correspond with the mark already made on the crankcase. Remove the adaptor locating device and turn the adaptor until the mark made on it comes as nearly in line with the centre of the tappets as the peg holes in the adaptor will allow. Replace the locating peg, screw in the cylinder and, when the central lining up of the cylinder is correct, the gap in the locking ring should be within the limits of ⅜ in. and ½ in. when tight.

The above procedure will only be necessary when fitting a new cylinder or if the adaptor has been disturbed.

NOTE.—Should the width of the locking ring gap not be within the limits of ⅜ in. and ½ in. the cylinder adaptor must be unpegged, turned clockwise or anti-clockwise a sufficient number of holes, as the case may be, and re-pegged.

Induction Pipes.—Slide the nut, brass ring, and packing gland over the induction pipe; fit the induction pipe into the induction case boss and cylinder port, making sure that the packing gland is not pushed into the induction case.

Press the packing gland into the cone seating in the inlet valve port flange, followed by the brass ring and screw up the nut with spanner SR.18371. Lock the nut by means of a circlip. The induction pipe flange is already in position on the induction case. Secure it with the four 2 B.A. nuts. Repeat for all other induction pipes.

Primer Pipes and Sparking Plugs.—Fit the primer pipes to the banjo pivots on the induction pipes and lock the nuts securely by means of tab washers. Fit the sparking plugs, spanner SR.37825.

Valve Rockers and Push Rods.—Rockers are stamped underneath the bearing housing thus: 2 IN for 2 inlet and 5 EX for 5 exhaust. Push rods are marked in a similar manner on the eye end. Assemble the push

rods and rockers so that their numbers coincide. The needle bearings of the push rod eye and rocker striker race should both work smoothly.

Rocker Standards.—Fit the push rods and rockers to their respective cylinders and valves. With the valves closed, tap the rocker fulcrum pins home so that their threaded ends point inwards.

If the valve seatings have been recut, it may be necessary to shim up the rocker standard in order to get the necessary range of adjustment on the eccentric rocker fulcrum pins.

To check the range of adjustment, turn the pin till the rocker is riding fully on the eccentric. The clearance between the rocker striker bearing and the end of the valve stem should be within the limits of 0·070 in. to 0·10 in. If it is less than 0·070 in., add a shim under the shoulder of the rocker standard.

Having checked and adjusted the clearance where necessary, lock the nuts on the rocker standards and remove the push rods and rockers.

Push Rod Covers and Brackets.—Before fitting the brackets smear a little graphite grease inside the tappet cups, and see that the oil hole in the cup is nearest the front of the engine.

Fit the leather seating washers inside the bracket bores.

Push rod covers have letters etched on the swaged ends to indicate their position in the engine, *i.e.* E for exhaust and I for inlet.

Fit the leather washers, brass push rod cover spring retainers, and springs into the push rod cover bracket, followed by the push rod covers. Fit the push rod cover sockets into the rocker cover platforms; there are two types of socket, one for exhaust and one for inlet.

Shellac the under-face of the bracket.

Insert the large ends of the covers into the sockets and gripping the push rod cover bracket, pull it towards the cylinder head to compress the springs. Guide the push rod cover bracket over the studs on the crankcase, fitting push rod cover bracket and covers in one. Secure the push rod cover bracket with nuts and spring washers. Repeat for all other push rod covers and brackets.

Push Rods.—Working from the ball end of the push rod, fit the spring retainer, the return spring, the cone collar and the collar retainer. The latter seats on the swaged portion of the push rod and is locked by the cone collar.

Fit the assembly into the push rod cover. With the push rod spring depressing tool inserted through the push rod cover socket, compress the spring until it is possible to insert the slotted retaining collar between the push rod cover socket and the top of the push rod cover.

Make sure that the spring retainer is seating properly in the slotted retaining collar before removing the spring depressing tool and allowing the cover to spring on to its seat.

Finally fit the rocker fulcrum pin and shims. Each rocker has four shims, two large and two small; the larger go nearest the rocker. Assemble the shims on either side of the rocker bearings and locate them with a taper pin. Ease the assembly as far as it will go between the supports of the rocker standard, remove the taper pin, tap the assembly into position with a hide hammer, locate the shims again with the taper pin, remove the pin and fit the rocker fulcrum pin and two cone nuts. Adjust the valve clearances and charge the rocker bearings with grease.

Ignition.

2 Magnetos B.T.H. SC.7-1.
Ignition fixed full advance.
Contacts on both magnetos break 28° early.
(Tolerance of plus or minus 1° is allowed).
Make and break gap 0·011½ in. to 0·013 in.
Sparking Plugs K.L.G. 752B, Lodge X.442B, 14 mm. K.L.G. V.14/1B.
Firing order: 1, 3, 5, 7, 2, 4, 6.
Fit the H.T. leads to cylinders from respective magnetos.

H.T. Leads (Testing.)—Check each H.T. lead from distributor to sparking plug to verify that the connections have been correctly made and that the leads themselves are not faulty. To do this use a pocket battery and lamp, placing one wire on a segment of the magneto distributor and the other wire on the sparking plug terminal of the lead under test. Unless there is a fault in the lead or the connections have been incorrectly made, the lamp will light. Repeat on all other leads.

Adjustment of Contact Breaker Gap.—Having made sure that the cam is in such a position that the contacts are at their widest, screw up the contact until it can be felt to nip the blade of the feeler gauge.

It should be remembered that the contacts are only held together by a spring, so that no matter how small the gap is, a larger feeler can always be inserted.

Check the gap on all open positions of the cam and adjust it so that the average gap is as near as possible to the specified setting, 0·011½ in. to 0·013 in. If any one gap is 0·003 in. greater or less than the specified setting, the cam must be renewed.

Fuel Pumps.—These pumps, although reliable, embody disc valves of a delicate nature. They should only be dismantled when absolutely necessary and when re-assembling make sure that the short valve stems enter the guides while the outlet valve cap and the inlet valve seat are being screwed into position. Otherwise, if undue force is used, the valves will be rendered unserviceable.

When fitting the disc valves, detach the pump body from the bracket. This will expose the lower or inlet valve to view so that the above conditions are obtained. The upper or outlet valve can be observed through the delivery union, whilst screwing the cap into position.

With normal use the pumps should only require dismantling at complete overhaul of the engine, when the condition of the valves, seats and diaphragm should be carefully examined for signs of deterioration.

CARBURETTOR.

Type A.V. 70.M.

Introduction.—Modern high-duty engines, supercharged and otherwise, make very exacting demands on the carburettor. High speeds require adequate pressure balance to the float chamber and appropriate air intake design to prevent alteration to the mixture occurring with changes in aeroplane speed. When once the design of the air intake has been determined in conjunction with engine tests, its shape should on no account be altered or the performance of the engine may be seriously affected.

Economy and Power.—Provision for economical cruising consumption, combined with the ability to get maximum power is made in these carburettors by the adoption of the power jet principle, which allows of the utmost economy under cruising conditions and still renders full power available as the throttle approaches its open position.

Slow Running.—The large induction systems on modern engines, especially if they are supercharged, require special attention to the slow running system to avoid flat spots and build-up when idling. This requirement is catered for by the special slow running system incorporating the transverse passage in the butterfly throttle, which both obviates a flat spot and provides a 3-point spray to minimise build-up difficulties.

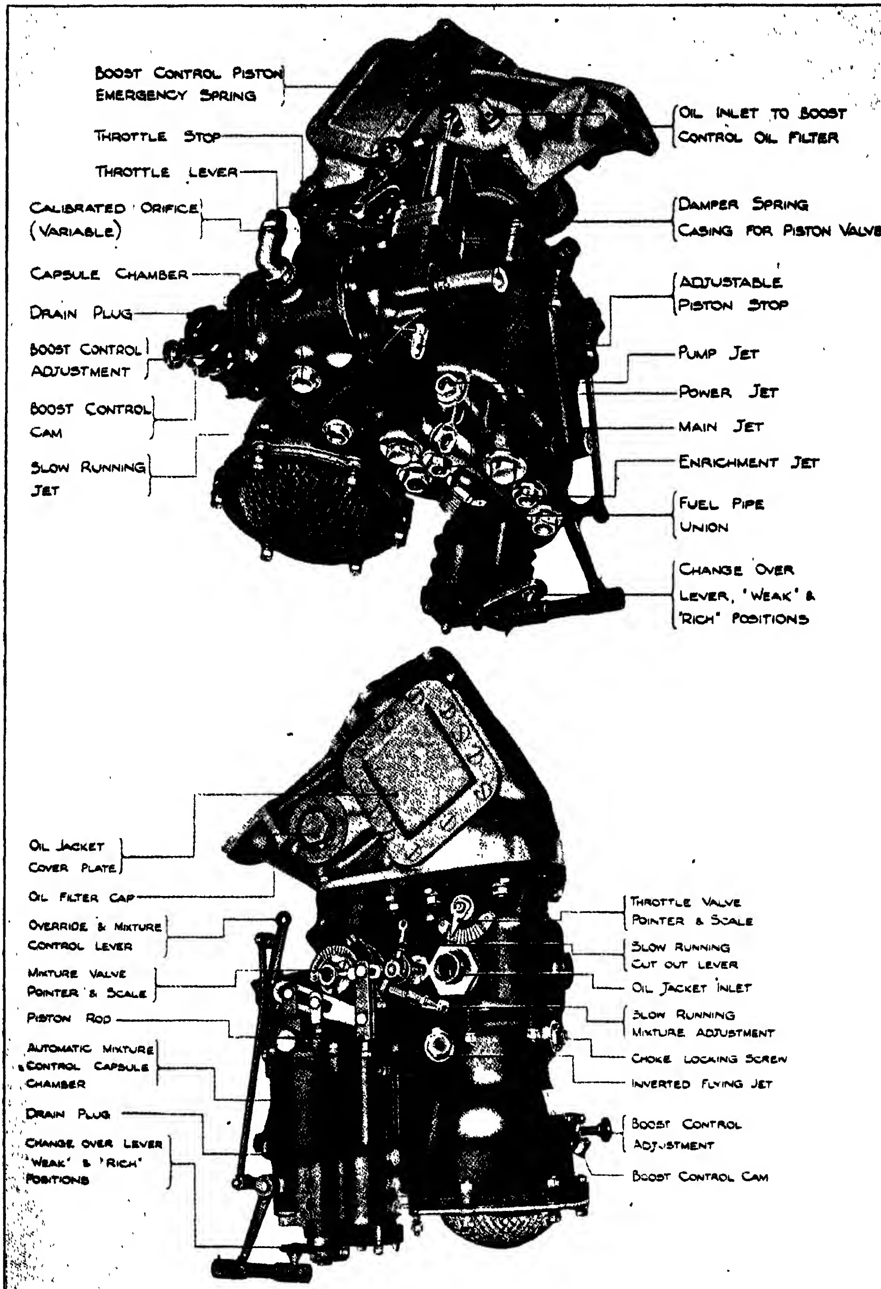
A slow running cut-out is provided for ensuring immediate stoppage of the engine after switching off.

Acceleration.—A delayed action acceleration pump is provided to enable the engine to accelerate on weak mixtures for cruising.

Additional Power for Take-off.—To overcome the known difficulty met with in highly supercharged engines in leaving the ground, an arrangement is incorporated in the carburettor by which an extra jet is brought into play in synchronisation with override of the boost control, and this allows of extra horse-power being available for take-off purposes without causing detonation or overheating.

Mixture Control.

The mixture control on these carburettors is completely automatic throughout the two ranges provided and gives correct mixture from sea level to the aircraft's ceiling. The pilot has a choice of two mixture strengths, namely a rich mixture for maximum power and manœuvrability, and a weaker mixture strength for economical cruising with reduced engine revolutions. It is, therefore, only necessary for the mixture lever to be placed in either of these positions when flying, the automatic instrument controlling the mixture strength in either range. These two positions are known as "automatic rich" and "automatic weak."



Figs. 20 and 21.—Claudel-Hobson Carburettor, Type A.V. 70.M.

Because of the amount of mixture control required at great heights, it is imperative that there shall be an interlocking gear which will move the mixture lever to the "automatic rich" position when the throttle is closed for a dive to ensure that the engine will open up again.

When used with the Hobson pilot's cockpit control the interlocking gear on this instrument automatically ensures that this will be taken care of, and makes certain that full power is not obtained on cruising mixture strengths. It is very important that no alteration whatever is made to the automatic mixture control and that the length of the connecting rods and links remains unchanged.

The automatic mixture control and the variable datum boost control are fitted on the sides of the carburettor, and the necessary oil pressure for operating the servo pistons in them is taken through the top flange.

Care must be taken that these oil holes, as well as the air hole for the boost override, are not partially blocked by using a flange washer with incorrectly sized or spaced holes.

Float Mechanism.—Care must be taken in handling the float to avoid damaging the varnish on it, otherwise it may become fuel logged.

The float needle and seat should have a minimum life of 600 working hours. Never grind needles in their seatings, it will spoil both. If there are signs of either being defective, fit a new pair. Never fit a new needle in an old seat or vice versa.

Handle a float carefully. Do not drop it or bend the float arm or the float may become porous.

To alter the level in the float chamber, washers of varying thicknesses may be put under the needle seating. Increasing the thickness of the washer will lower the fuel level.

The positions of all jets are marked and they are accessible for cleaning purposes.

The standard setting for the carburettor is as follows :—

Choke, - - - -	60 mm.
(streamlined, inverted).	
Main Jet, - - -	1425 cc.
Power Jet, - - -	320 cc.
Slow Running Jet, -	285 cc.
Power Valve Bleed Jet,	225 cc.
Enrichment Jet, - -	195 cc.
Delayed-action Pump Jet,	560 cc.
Slow-running Restriction Plugs :	
At Throttle, - -	2·5 mm.
Under Throttle, -	2·5 mm.

An oil filter is located in the induction elbow and should be cleaned regularly in order to ensure an adequate oil supply to the boost control and the automatic mixture control.

Jets.—Care should be taken when screwing these in and out of the carburettor. Should a jet feel tight whilst being screwed in, or have a tendency to seize, the jet should on no account be forced into place or serious damage to both jet and carburettor body may result.

Remove the jet and look for the cause. Examine the threads of the body for dirt or portions of thread torn from the jet through careless fitting and jammed in the thread in the body. Excessive tightening of parts such as jets, etc., may permanently damage the threads in the body and even stretch the threads of the jet out of pitch, thereby causing difficulty both in screwing and unscrewing. Jets and similar parts which are obviously damaged in this way should be replaced by new ones.

Removal of Plugs.—The foregoing remarks apply to these parts also, and only box spanners which are a good fit for the heads should be used.

Stripping.—It will be helpful if the sectional drawing of the carburettor be first studied.

On no account remove the throttle plate from the spindle. When all the necessary fixing screws, nuts and connections are removed, the top and bottom halves of the carburettor can be separated. This requires great care, or damage may be done to the float, pump mechanism and choke. If the two halves have not been separated for some time a light tap with a rubber or hide mallet on the lower portion may be necessary to "break" the joint, but if the two halves still resist separation, examine carefully for fixing screws or similar locking devices which have been overlooked.

Memorize or make a note of the order in which the parts are removed. Clean all parts in pure petrol. Avoid the use of alcohol or alcohol-petrol-benzole mixtures for cleaning purposes. Examine all internal parts and passages for signs of corrosion due to bad fuel or long standing deposits of water.

Any signs of corrosion should be removed at the discretion of the person engaged in cleaning, care being taken not to damage machined or jointing faces, calibrated orifices and the like.

Check all valves below fuel level, spring-loaded or otherwise, for freedom of movement and fuel tightness, and after assembly check operation of accelerating pump by filling float chamber with fuel and moving pump operating lever two or three times.

When bending copper tab washers care must be taken not to crack the ear. Tab washers must on no account be used more than once.

Wherever possible, fit a new body gasket of approved material and correct thickness, as old or broken gaskets may cause leakage of fuel and air and upset the functioning of the carburettor. The choice of gasket material is important, and only the type and thickness recommended by the makers should be used.

On no account alter the size of the holes in the diffusers.

Checking Fuel Level.—The carburettor should be coupled up to a fuel tank arranged to give a head of ten inches, measured from the actual seating of the needle, provision also being made for raising this tank to a height of 12 ft.

The needle mechanism should be set to cut off at the correct level and to maintain fuel tightness up to the maximum head of 12 ft.

The fuel level in the carburettor, when properly set, should be approximately 28 mm. at 2 lb. pressure (6 ft. head).

The above measurement is to be made from the fuel level to the parting face and must be taken with the top of the carburettor removed.

When fuel level is being checked with top half removed, checks can also be made to see if enrichment and pump valves are sound by removing plugs underneath and inspecting for leakage.

Periodical Cleaning.—Routine inspection of the engine should include the carburettor. Drain plugs should be removed and examined for dirt or water. This latter inspection should always be done immediately after flying through rain or cloud.

The carburettor should be taken apart for cleaning and inspection on every occasion the engine is given an overhaul, or when the carburettor is

known to be functioning in an unsatisfactory manner, or after an accident in which damage may have been done to the carburettor.

Dirt of any sort, including excess of oil or grease, should be wiped off, and split pins, washers, fork ends, screws, locking nuts and wiring, etc., examined for wear, loss or breakage.

Check all connections right through to the pilot's control levers.

Lubrication.—All obvious bearing surfaces such as pins, cams, wipe contact springs, etc., should be lubricated after every ten hours' flight, and steel parts lightly greased as a protection against adverse atmospheric conditions. Grease must not be used inside the float chamber.

RUNNING IN.

If a major replacement such as a piston, cylinder, big end bearing or a majority of piston rings has been made during top overhaul, the engine should undergo a period of light running and an endurance test before being returned to service. The running-in period varies according to the type of test plant available. The following is a schedule for three possible cases where major replacements have been made :—

A. TEST BED.

B. TEST FAN.

C. IN AIRCRAFT.

Before starting the test make sure that the Detail Lubrication Instructions and the Final Inspection have been carried out.

An external method of heating the oil should be employed ; with the engine running at normal R.P.M. the oil going into the engine should be at a temperature of not less than 55°C.

Castor oil must be used during the run in.

Mineral oil must be used for the endurance test. The castor oil must be run out and the mineral oil run in while the engine is hot and idling.

The absence of castor oil will be readily seen at the scavenge outlets by the fresh mineral oil running through.

The mixed oil should be kept separate and not used again for testing engines.

The engine is now run in again on mineral oil in accordance with items 1 to 4 below, but the periods are reduced by half.

A and B.—(1) Start running light ; carry out all preliminary observations.

(2) Proceed with running in at 600 to 800 R.P.M. for one hour.

(3) Continue at 1000 R.P.M. for one hour.

(4) Increase to 1300 R.P.M. and in increments of 100 R.P.M. every ten minutes up to 2100 R.P.M.

(5) Carry out Endurance Test in accordance with current instructions.

(6) Part strip to inspect replacements ; rebuild.

(7) Run in again for half the time given in sections 1 to 4.

(8) Final Test according to current instructions.

C.—With the engine warm, run it for one hour at 1200 R.P.M.

Part strip and inspect replacements. After rebuild run the engine up as instructed in Preliminary run ; and, during the first hour's flight, on no account exceed the cruising speed.

The above schedule is a guide to be followed or modified at the discretion of the Technical Officer.

Supply of Additional Oil and Upper Cylinder Lubrication.

While the engine is being run in, it is most important that an adequate supply of oil shall reach the cylinder wall, crankshaft bearing and other moving parts. This applies especially to starting up for the first time with either a brand new engine or one which has just been overhauled. The absence of auxiliary lubrication under such conditions may cause irreparable damage.

Upper cylinder lubrication is effected by pumping oil into the air intake, whence it is drawn through the induction system into the cylinders.

The apparatus used for this purpose by the constructors consists of a 2 H.P. electric motor driving a standard Jaguar oil pump at approximately 900 R.P.M. The arrangement is shown in Fig. 22.

Oil is pumped :—

(*a*) Past a cock to the banjo type oil union on the pump, through which oil is forced via the oil filter to the crankshaft bearing.

(*b*) Through a second cock to the air intake of the engine. This pipe leads to a union welded to the end of a half-inch tube, the latter being fitted horizontally in the bore of the flight intake, one end being blanked and the other fitted to the above-mentioned union. A three-eighth inch pipe with a 0·7 in. diameter rose head spray having nine 1 mm. holes drilled in it is fitted to the transverse tube and is set to clear the delivery tube in the carburettor choke.

(*c*) Through a third cock to a slave eyebolt to be fitted in the crankcase between Nos. 1 and 2 cylinders.

Oil is fed from the tank to the auxiliary oil pump through a T-piece from which a second pipe is taken to the main engine pressure pump, whence it is circulated through the engine in the ordinary way and returned by the two engine scavenge pumps through separate pipes back to the cooler and thence to the main tank. From the delivery port of the scavenge section of the priming oil pump a pipe is led to a T-piece on the crankcase scavenge return to scavenge any oil which may be by-passed into the scavenge pump casing by the relief valve.

A blanking cap must be fitted to the union on the auxiliary pump which is marked "A" on the diagram.

The oil pipe leading from the priming pump to the bottom union on the port side of the engine oil pump is merely for priming the crankshaft. The electric motor must be switched on and the cock should be left open before starting the engine until a pressure of 40-50 lbs. is registered on the gauge, at which point the cock should be closed.

While the engine is being run in it is most important that an adequate supply of oil should reach the cylinder wall to prevent scoring. This applies particularly to starting up an engine for the first time after an overhaul.

Accelerate the engine up to 1200 R.P.M. in order to suck the oil up the induction system, and, when all exhausts show blue smoke, bring back the throttle lever to the prescribed position for running in and turn off the cock. If this is not done, the upper cylinder lubricant will be burned up instead of remaining in the cylinders.

Repeat the operations necessary for ensuring adequate upper cylinder lubrication every five minutes while the engine is running in, but when the

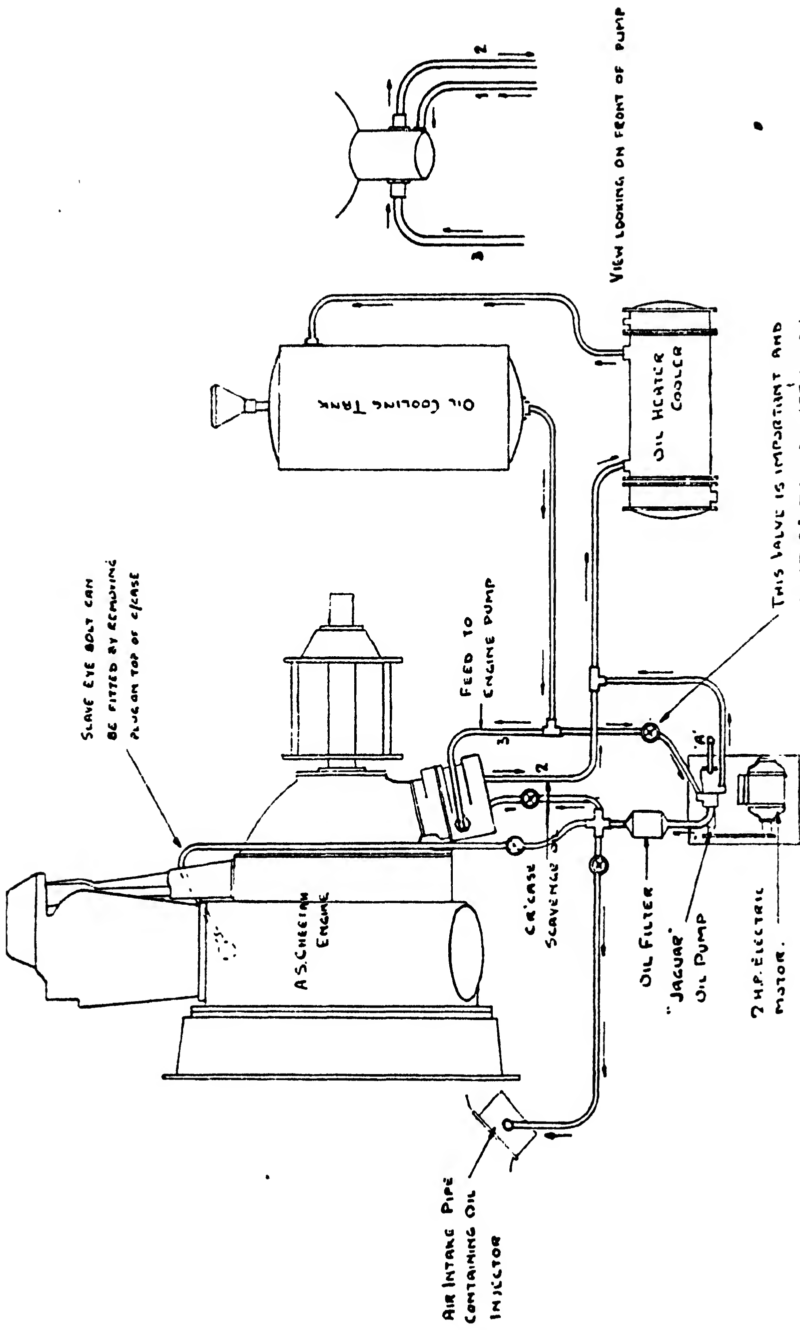


Fig. 22.—Upper Cylinder Lubrication Arrangement for Running In.

engine speed is 1000 R.P.M. or more, it is not necessary to accelerate in order to ensure the oil passing through the induction system and reaching the cylinder walls.

NOTE 1.—If, for any reason, it is found necessary to stop the engine during the process of running in, even for a very short period, it is essential that crankshaft priming, as described above, shall be resorted to before the engine is restarted.

NOTE 2.—For the Endurance Test, upper cylinder lubrication is discontinued.

RADIAL.

PART 2.—BRISTOL—"PEGASUS."

By E. W. DENSHAM,
Aircraft Engine Inspector, Civil Aviation Directorate, Government of India.
Late Head of Technical Publications Dept., Bristol Aeroplane Co., Ltd.

INTRODUCTION.

The Pegasus series of engines are of the well-known Bristol type, nine cylinder air-cooled static radials. Altogether there are no less than fourteen different series excluding experimental types. They are, however, divided into groups of series in which the difference is the reduction gear ratio

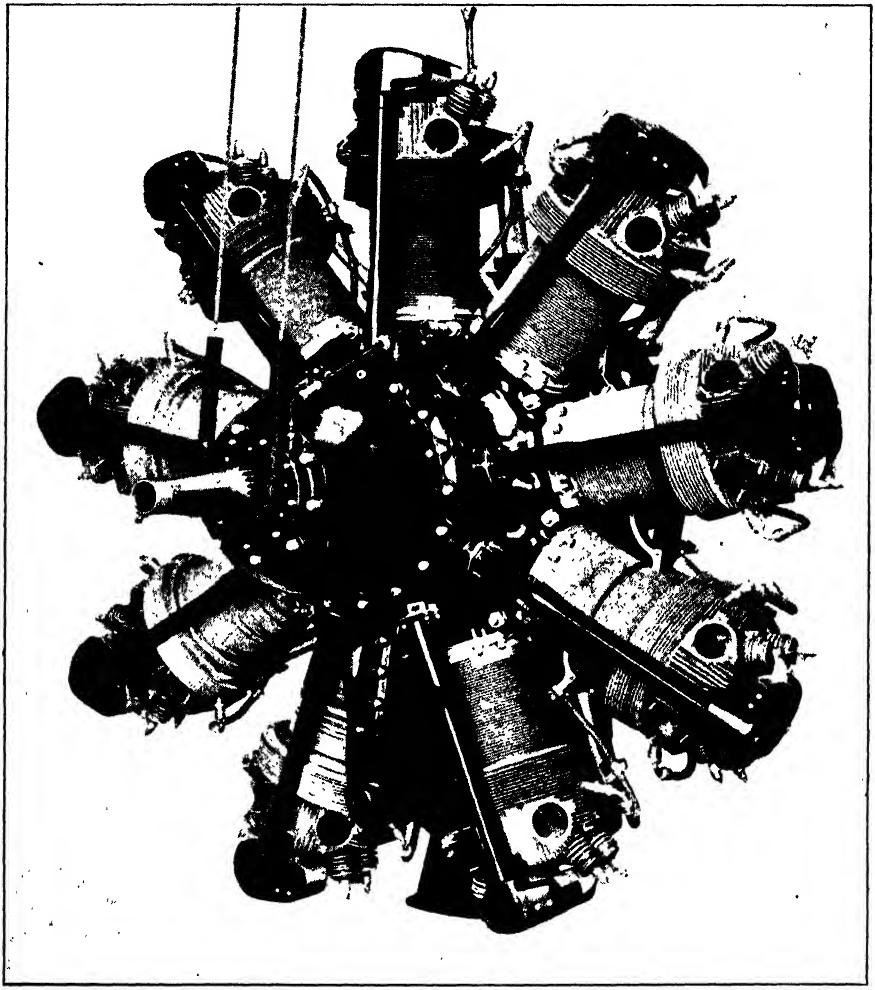


Fig. 1.—Three-quarter Front View of "Pegasus" Engine.

and supercharger. For instance the Pegasus X, XI and XII are identical, except that the Pegasus X has a 0·500 : 1 gear, the XI a 0·572 : 1 gear, and the XII. a 0·666 : 1 gear. The later type engines are, of course, improved in various respects as the result of development and research work carried out over a number of years. Improved materials have permitted a considerable increase in power and speed with a corresponding improvement

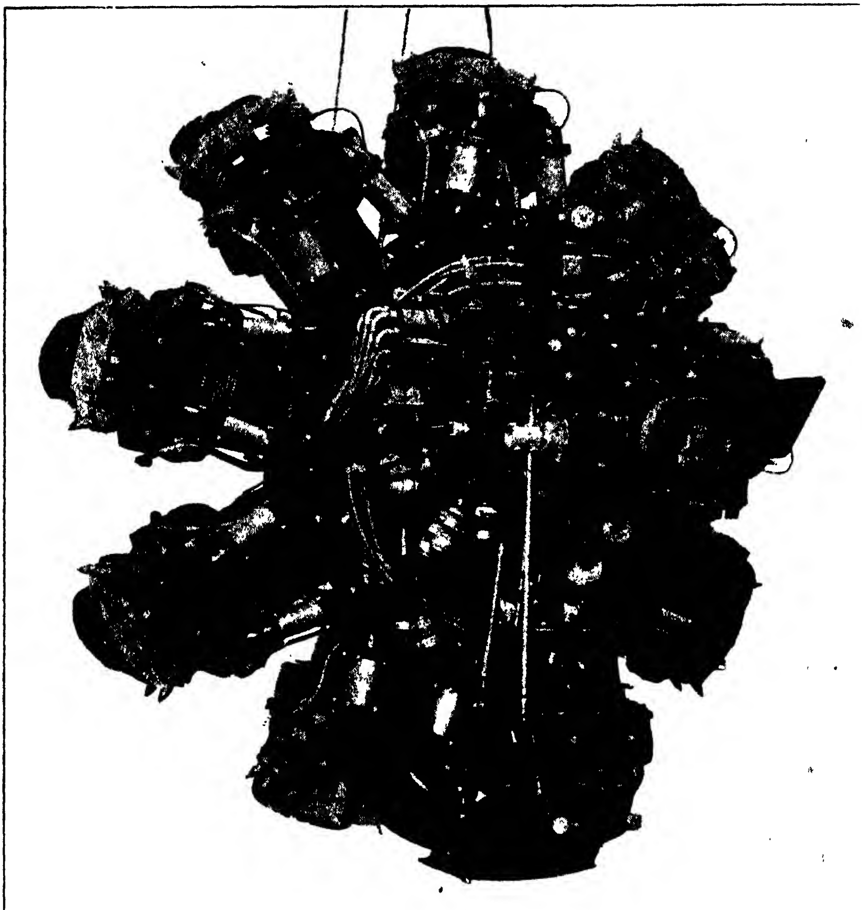


Fig. 2.—" Pegasus " Engine—Three-quarter Rear View.

in fuel consumption. From time to time the aircraft designer has demanded certain accessories, such as vacuum pumps for operating flaps and flying instruments, oil pumps for operating gun turrets, etc., all of which have materially increased the gross weight of the engine. It is therefore very much to the designer's credit that the power/weight ratio has not materially altered, although he would be the first to admit that it is the metallurgist and the fuel and oil technologist who have made these higher powers possible.

LEADING PARTICULARS.

The following particulars are common to all series of Pegasus engines :—

CYLINDERS.

Number of cylinders - - - -	9
Disposition - - - - -	Equally spaced radially.
Bore - - - - - - -	5·75 ins.
Stroke - - - - - - -	7·5 ins.
Stroke/Bore ratio - - - -	1·305
Swept volume per cylinder, cub. ins.	195.

VALVES.

Number of valves per cylinder Inlet	2
Number of valves per cylinder - - - Exhaust	2
Method of operation - - -	Push rod.

IGNITION.

Number of magnetos - - -	2
Speed of rotation - - - -	$1\frac{1}{8}$ Engine Speed.
Direction of rotation - - -	Anti-clockwise.
Order of firing - - - - -	1, 3, 5, 7, 9, 2, 4, 6, 8.
Number of spark plugs - - -	2 per cylinder.

LUBRICATION.

System of Lubrication - - -	Pressure feed to master rod, big end and articulated rod pin bearings, cam gear, rear cover and reduction gear. Remainder by splash.
Temperature of oil entering engine. Max.	80° Centigrade.
Ratio of oil pump drive to crankshaft	1 : 1
Specification of lubricating oil - -	D.T.D. 109.

STARTERS.

Eclipse Hand Turning Gear.
,, ,, Inertia Starter.
,, ,, and Electric Turning Gear.
,, ,, ,, ,, Inertia Starter.

The following proprietary brands of oil are approved by the Bristol Aeroplane Co. for use in their engines. Under no circumstances should castor oil be used.

For Use under Temperate or Tropical Climatic Conditions.

Alfred Olsen and Co., - - - - -	Elektrol " H."
Red Line—Glico, - - - - -	Super Aero Oil—Summer.
J. Arnott and Sons, - - - - -	Arnoco.
Shell-Mex and B.P. Ltd., - - - -	Shell 387.
C. C. Wakefield and Co. Ltd., - - -	D.T.D. 109.
W. B. Dick and Co. Ltd., - - -	Ilo. Aero Engine Oil " M."

Sternol Ltd., - - - - - -	D.T.D. 109.
Silvertown Lubricants, - - - -	Speedolene P.4.
Alexander Duckham and Co. Ltd., - -	D.T.D. 109.
Anglo American Oil Co., - - - -	Marvelube A. 5.
Ragosine Oil Co. Ltd., - - - -	Ragosine "Minix."
Anglo Iranian Oil Co., - - - -	B.P. Aero Oil Medium.
Texas Oil Company, - - - - -	Texaco Airplane Oil 100.
Asiatic Petroleum Co. Ltd., - - -	Aeroshell 100.
Intava, Ltd., - - - - - -	Red Band 100 M.

For Use under Arctic Conditions.

Intava, Ltd., - - - - - -	Grey Band.
C. C. Wakefield and Co. Ltd., - - -	Castrol "AA."

Owing to the lower viscosity of Arctic type oils, the temperature of the oil leaving the crankcase must not exceed 90°C. even under the most arduous operating conditions.

LEADING
PEGASUS

SERIES	II-L	II-M	Fixed Pitch III	VI
Reduction Gear Ratio . . .	0·5-1,	0·666-1,	0·655-1	0·666-1
International R.P.M. of Engine, .	2000	2000	2200	2425
Maximum permissible R.P.M. of engine	2300	2300	2525	2525
Take-off R.P.M. of engine . .	1900	1835	2090	2425
Maximum cruising R.P.M., . .	2000	2000	2200	2200
NOTE :—The International R.P.M. must not be exceeded for periods of more				
International Boost. Lbs./sq. in., .	+ ¼	Zero	+ ½	+ 2
Maximum permissible boost for take-off. Lbs./sq. in.	+ 1¼	+ 1½	+ 2	+ 2
Blower Gear Ratio, ...	5·7-1	7-1	7-1	
Impeller R.P.M. at International Speed of Engine, ...	11400	14000	15400	16975
International Altitude of Engine. Feet,	2000	5000	3500	1000
B.H.P. at International R.P.M. at International Altitude, . . .	580/600	560/580	665/690	790/820
Maximum Power Altitude, . .	2500	6500	4750	1250
Maximum B.H.P. for Take-off, .	700	670	825	785/815
Maximum B.H.P. at Maximum R.P.M. at Maximum Power. . . .	630/650	615/635	725/750	810/840
Valve Timing :—I.O., ...	12° B.T.C.		29° B.T.C.	
I.C., ...	50° A.B.C.		47° A.B.C.	
E.O., ...	65° B.B.C.		76° B.B.C.	
E.C., ...	31° A.T.C.		40° A.T.C.	
Magneto Timing, ...	35° B.T.C.		31° B.T.C.	
Type of Carburettor, ...	Claudel Hobson A.V.T. 80 B.			
Specific Fuel Consumption—Pts./B.H.P./Hr. at Rated Power .	0·590	0·610	0·600	0·690
Approved Economical Fuel consumption, Pts./B.H.P./Hr., . . .	0·500	0·500	0·500	0·500
Type of Magneto, ...	B.T.H. S.C. 9-5B		B.T.H. S.C. 9-7B.	
Maximum Cruising Boost, . .	+ ¼	Zero	+ ½	+ ½
Maximum Boost (for 5 mins.) . .	+ ¼	Zero	+ ½	+ 2
Oil Pressure: Lbs./sq. in. . .	60		60	100
Oil Temperature. Inlet Desired, .	50° C.		50° C.	50° C.
Oil Consumption. Pints per Hour, .	8-16		6-10	6-12
Weight of Engine, ...	970 lbs.	980lbs.	1000 lbs.	
Overall Length, ...	42·3 inches.		35·8 inches.	

PARTICULARS
ENGINES

IV, VIII	X, XI, XII	Variable Pitch XIX, XX, XXI	XXII, XXIII
IV: 0·5-1 | VIII: 0·666-1	X: 0·5-1 | XI: 0·572-1 | XII: 0·666-1	XIX: 0·572-1 | XX: 0·5-1 | XXI: 0·666-1	XXII: 0·5-1 | XXIII: 0·572-1
2250	2250	2250	2250
2600	2600	2600	2600
1900	2475	2475	2600
2250	2250	2250	2250
than 5 consecutive minutes.			
+ ½	+ 2½	+ 3	+ 2½
+ 2½	+ 4½	+ 4¼	F.T.
10-1	7-1	9·4-1	7-1
22500	15750	21150	15750
11500	4000	8500	4000
640/670	810/850	800/835	800/840
15000	6250	10000	6500
720	920/960	800/835	1010
680/710	875/915	890/925	890
29° B.T.C.	29° B.T.C.	29° B.T.C.	29° B.T.C.
47° A.B.C.	47° A.B.C.	47° A.B.C.	47° A.B.C.
76° B.B.C.	76° B.B.C.	76° B.B.C.	76° B.B.C.
40° A.T.C.	40° A.T.C.	40° A.T.C.	40° A.T.C.
31° B.T.C.	29° B.T.C.	S.C.B. 29° B.T.C. D.C.B. 29° & 35°	Retard 27° B.T.C. Advance 35° B.T.C.
A.V.T. 80 B.	A.V.T. 85 E.	A.V.T. 85 E.	A.V.T. 85 E.
0·610	0·660	0·670	0·660
0·550	0·515	0·540	0·515
B.T.H. S.C. 9-7B	B.T.H. S.C. 9-7B	B.T.H. S.C. 9-8 Dual Contact Breaker.	B.T.H. S.C. 9-8 Dual Contact Breaker.
+ ½	+ 2½	+ 3	+ 2½
+ ½	+ 2½	+ 4¼	+ 2½
60	80	80	80
50° C.	70° C.	70° C.	70° C.
6-14	6-12	6-12	4-12
1000 lbs.	1005 lbs.	1020 lbs.	1040 lbs.
35·8 inches.	35·8 inches.	35·8 inches.	35·8 inches.

GENERAL DESCRIPTION.

Crankcase.—A drop stamped aluminium alloy crankcase constitutes the main body of the engine; it is built up from two halves, the joint face being on the centre line of the cylinders. The two halves are assembled by nine bolts and nuts. It is machined to receive the nine cylinders, whilst nine pairs of bosses around the crankcase front half are bored and faced to provide a two stud housing for the tappet guides. The intermediate and rear main bearing housings are shrunk and located in the front half and rear half wall respectively.

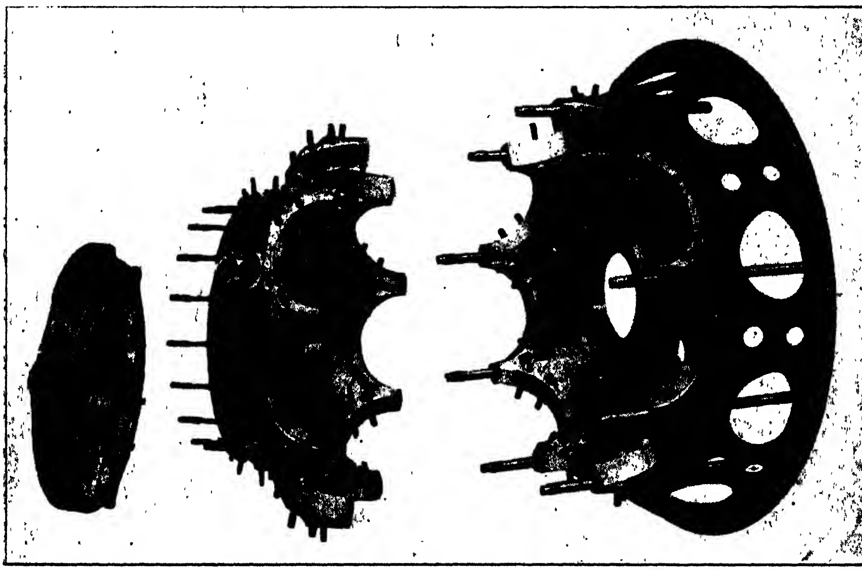


Fig. 3.—Crankcase—Front Half with Front Cover, and Rear Half with Cone Mounting.

Front Cover.—Attached to the front half of the crankcase by studs, is the front cover. This casting houses the main front thrust bearing and also carries the front end of the cam gear layshaft. An oil drain hole and tray are provided to regulate the oil supply to the reduction gear casing.

Cone Mounting.—In order to standardise the method of retaining the engine in the air frame, a cone mounting is provided. It is made in the form of a truncated cone and located on a spigot at the rear of the crankcase. Openings are provided for the induction branch pipes and high tension wires.

Oil Sump.—As the lubrication system is arranged on the dry sump principle (see Figs. 4, 31 and 32), a separate light alloy sump is carried on the crank-case between the two bottom cylinders. At the rear end in the oil sump cover are two oil connections, one for a drain pipe from the engine rear cover and the other for an oil return pipe leading to the scavenge side of the

oil pump. On late Pegasus engines a breather vent is incorporated at the front end in order to prevent oil frothing. At the bottom, and housed in a separate chamber within the sump, is a cylindrical oil scavenge filter, which can be withdrawn for periodical cleaning.

Crankshaft.—The crankshaft is made up of three pieces; the front half, which includes the crankpin, the rear half and the tail shaft. The crankwebs, the extensions of which form the main balance mass, are fitted with auxiliary balance weights. The top of the rear crankweb is bored

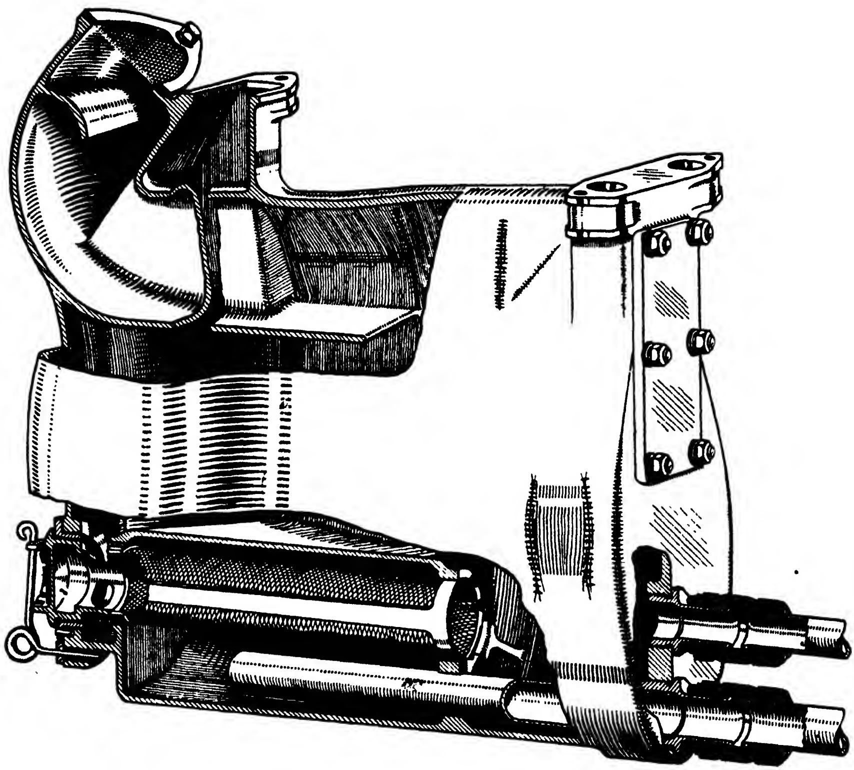


Fig. 4.—Perspective Sectional View of Oil Sump.

and split to receive the rear end of the crankpin, which is gripped by a transverse bolt and nut. To align the two halves of the crankshaft, a key is formed in the coupling bore diametrally opposite to the bolt and enters a corresponding slot in the crankpin rear end. From Pegasus X onwards this key is deleted, as it is found that with the maneton bolt nut pulled up the correct amount, a satisfactory coupling is ensured. The crankpin and shaft are hollow, with the ends blanked by caps, to provide a passage for the oil which is introduced at the rear end of the tail shaft. On certain later engines, the caps are deleted and the ends made solid with the crankshaft. The shaft is borne in one ball bearing and two roller bearings,

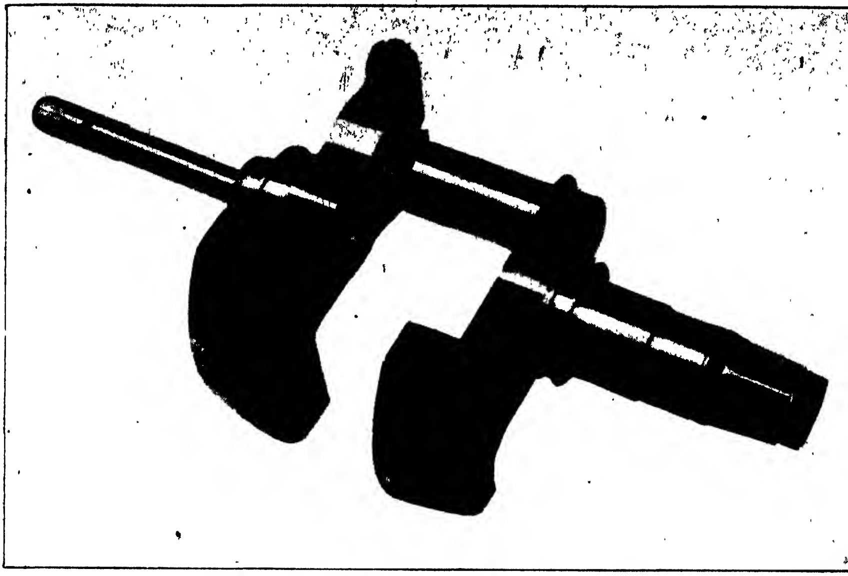


Fig. 5.—Crankshaft—Front and Rear Halves.

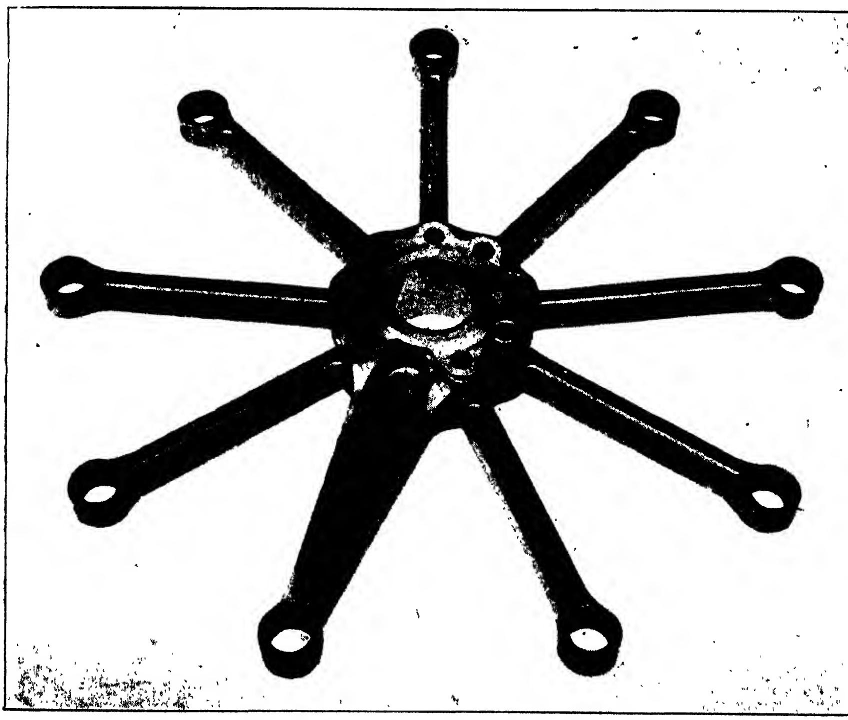


Fig. 6.—Connecting Rod Assembly with Floating Bush and Oil Retainer.

known as the front, intermediate and rear main bearings respectively. The front half crankshaft has taper splines machined to receive the reduction gear driving member, whilst the rear half is quite short and carries the supercharger driving gear and tail shaft. The tail shaft is driven through splines machined in the rear bore of the crankshaft and is used to transmit the drive to the various auxiliaries, mounted on the rear cover, through two integral gears machined on the starter jaw, which in turn is splined to the extreme end of the shaft.

Connecting Rods.—The connecting rod assembly comprises a master rod and eight articulated rods, the latter being secured to the big end of the master rod by eight articulated rod pins.

The master rod, which is located in No. 6 cylinder, is of H section, with two flanges formed round the big end bore and suitably machined to accommodate the pins, the articulated rod pin eyes being registered between the flanges. A bush is shrunk and riveted in the small, or piston, end of the master rod to accommodate the gudgeon pin.

In the big end of the master rod is housed a steel floating bush, white-metalled on both sides and the rear face to provide suitable bearing surfaces for the crankpin, big end bore and inside face of the rear web. It is freely drilled for lubrication. The eight articulated rods, also of H section, are machined all over and have bushes shrunk and riveted in both the gudgeon pin and articulated rod pin eyes. The articulated rod pins, which are hollow for most of their length, are machined to accommodate a short securing bolt, whilst at one end, on the outside, a taper is ground which locates in a corresponding taper in the master rod flange. The articulated rod pin bolts, in addition to securing the pins, hold the front oil retainer. The retainer, having eight lobes, is centralised around the connecting rod floating bush and is located by a small bush in No. 4 pin. This retainer is provided to collect oil passing out from the big end, whence it is taken through channels to the front end of each articulated rod pin. The oil is then directed through two oil holes drilled in the pin to two flats, machined diametrically opposite on the outside of the pin. In order to prevent the oil passing out through the rear end of the bush, an oil retainer is fitted. It is located by a tongue which registers in the shank of the master rod. Three equally spaced spring loaded plungers, located in the bore of the wrist pin, are provided to maintain surface contact between the retainer and inside face of the rear crank web.

Pistons and Piston Rings.—The forged aluminium alloy pistons are of the full skirted type. The crowns are concave in the case of Pegasus II-L and II-M, flat for Pegasus III., IV., VI. and VIII. and convex for the remaining series. This is due to the variation in compression ratio of the different series.

The gas and scraper rings also differ on various series of engines. Pegasus II to VIII, inclusive, have four cast iron rings. Of the three fitted above the gudgeon pins, the top two are gas rings, whilst the third is an oil scraper ring. This scraper ring is of U section, having holes drilled through the bottom of the groove to conduct the oil to drain holes in the bore of the piston ring groove. Below this scraper ring is a groove machined in the piston and freely drilled to assist oil drainage. The fourth ring, which is a scraper ring, is fitted below the gudgeon pin and is of square section. On No. 6 piston the ring has less pressure, in order

to allow more oil to get to the walls of this, the most heavily loaded, cylinder.

From Pegasus X onwards, five cast iron rings are fitted, four above the gudgeon pin and one below. The two top rings are bevelled gas rings, (the bevel is approximately 1° and must not be confused with the lower scraper ring), and are fitted with the bevel uppermost. The third and fourth are oil scraper rings, the lower being scalloped to provide oil drainage. Both these rings are fitted in the same groove, the scallops of one butting against its companion ring above. The fifth ring, below the gudgeon pin, is also a scraper, similar to the earlier pistons. On No. 6 piston, the upper scraper ring is of U section. Below the bottom scraper ring is a drilled oil groove, but interrupted in this case at the thrust faces to assist lubrication.

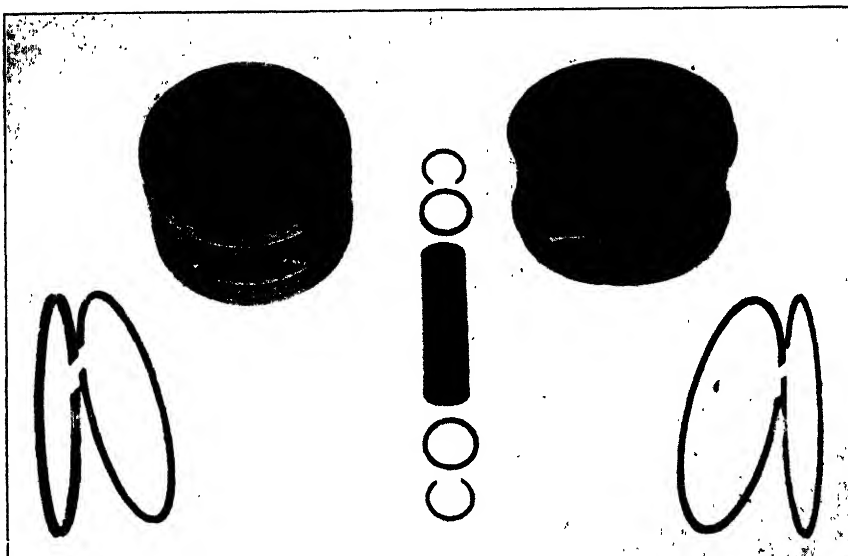


Fig. 7.—Piston and Rings, showing Gudgeon Pin and Circlips.

Gudgeon Pin.—The hollow, fully floating gudgeon pin is of air hardened steel. It is retained in position by two hardened washers, one at each end, which are in turn secured by piano wire circlips, which lie in a semicircular groove in the pin. One side of the washer is chamfered to accommodate the circlip and at the same time prevents incorrect assembly.

Cylinders and Valves.—Each cylinder consists of a steel barrel on to which is screwed and shrunk the cylinder head. The barrel has close pitch fins machined for the greater part of its length. A spigot is formed at the lower end for location in the crankcase, whilst a large flange is machined and drilled to receive the holding down studs, by which it is retained to the crankcase. Each cylinder is secured by eight studs and nuts, an oil tight joint being made by means of a rubber ring. The top of the cylinder barrel is screwed to receive the cylinder head, which is a

Y alloy forging, heavily finned and having a combustion chamber of the penthouse roof type.

On later engines the finning both on head and barrel has been increased in order to cope with the increased temperatures resultant upon the higher power output. The total increase over the whole series is in the region of 80 per cent., whilst in the case of the cylinder head, the increase has been approximately 130 per cent.

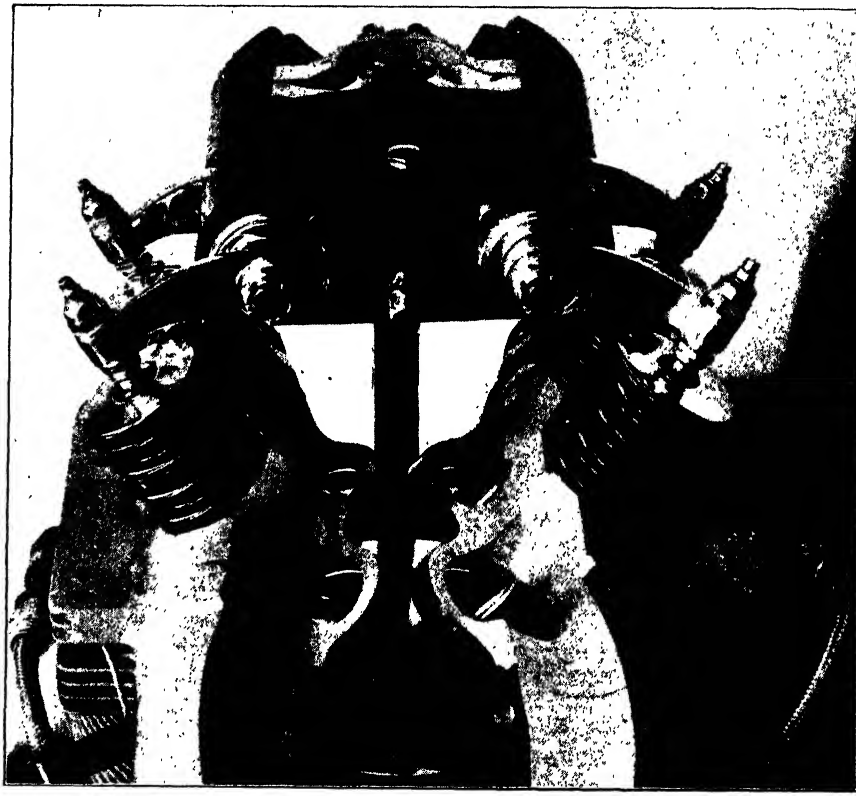


Fig. 8.—Rocker Gear and Valve Gear—Sectioned.

Four valve seats are screwed and shrunk into the head. On early engines these are of aluminium bronze, but later types are of special alloy steel. The four valves, two inlet and two exhaust, work in phosphor bronze guides. The valve stems are nitrogen hardened to resist wear, whilst on later Pegasus engines, the exhaust valve stems are sodium cooled and the seats of both the valve and seating are specially treated to resist wear and the corrosive effect of leaded fuel. There is 1° difference in the valve seat and seating angles in order to maintain maximum contact of the valve and seating under running temperatures. Pressed into the end of the valve stems are hardened buttons to withstand the continual attack of the rocker buttons. Three valve springs are fitted to each valve. They are

located between a lower washer on the cylinder head and an upper washer, the latter being retained in position by grooved split cotters and the pressure of the springs. An oil seal is fitted on the top of each inlet valve guide in order to prevent gas leakage at altitude. On series II to VIII, individual lubrication to the valve guides is arranged. This, however, is deleted on later engines.

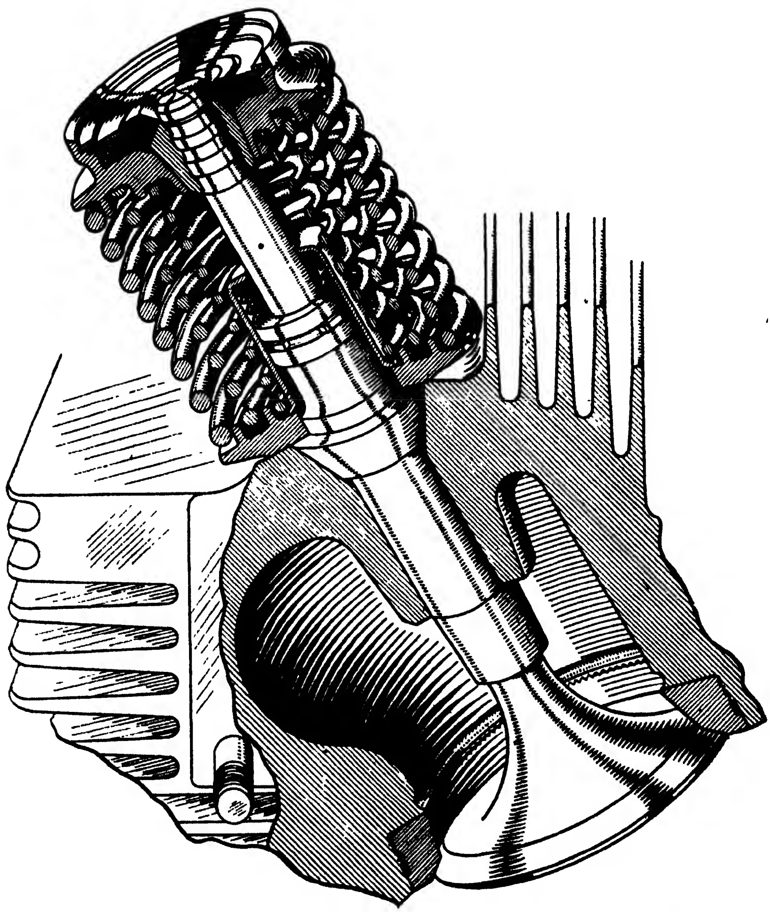


Fig. 9.—Perspective View of Valve, Valve Guide and Spring Assembly.

Rocker Gear.—The rocker gear consists of a forged bracket carrying two sets of concentric rocker shafts which lie parallel with each other. Each inlet rocker shaft runs the whole length of the bracket and carries the ball bearings which support its companion exhaust rocker. In order to obtain the correct clearance between valve and rocker, adjusting screws, having large headed floating buttons, are provided. Grease nipples are provided for lubrication. Non-adjustable floating buttons are also provided at the front end of the rocker arms to transmit the attack from the push rod

heads. The tubular push rods transmit the outward movement of the tappet to the rocker arms, suitable springs being fitted to maintain normal working position. To ensure long life, felt pads are fixed on the rocker bracket and cover to lubricate the heads of both inlet and exhaust push rods. A magnesium alloy cover, retained by two set screws with locking clips, prevents the entry of foreign matter and retains the grease. At the rear end of the bracket are two trunnion arms which locate in two pillars mounted on the cylinder head ; it is thus free to pivot about this point. The front end is secured by a bolt to the tie rod, which in turn is attached to the tappet guide bosses on the crankcase.

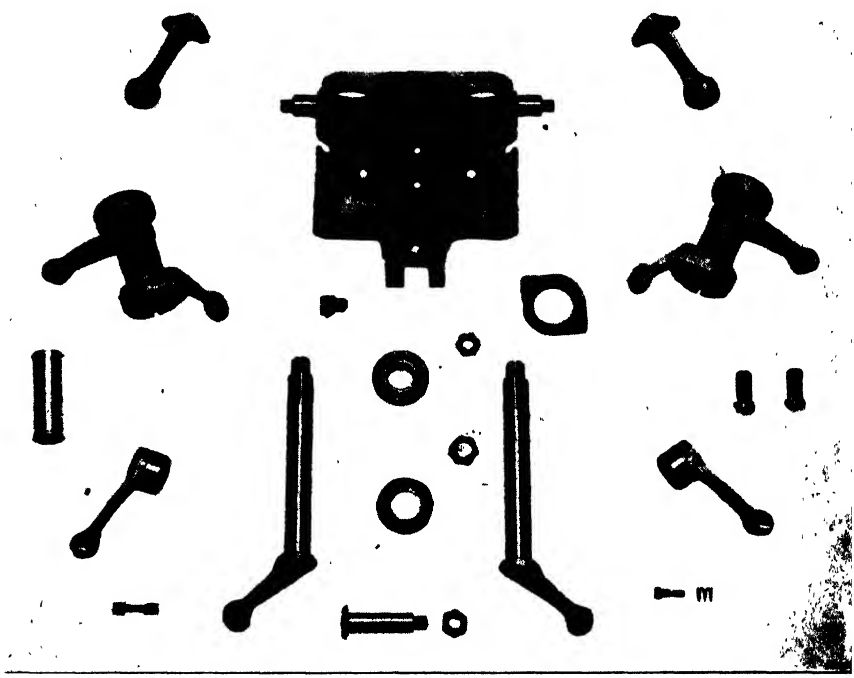
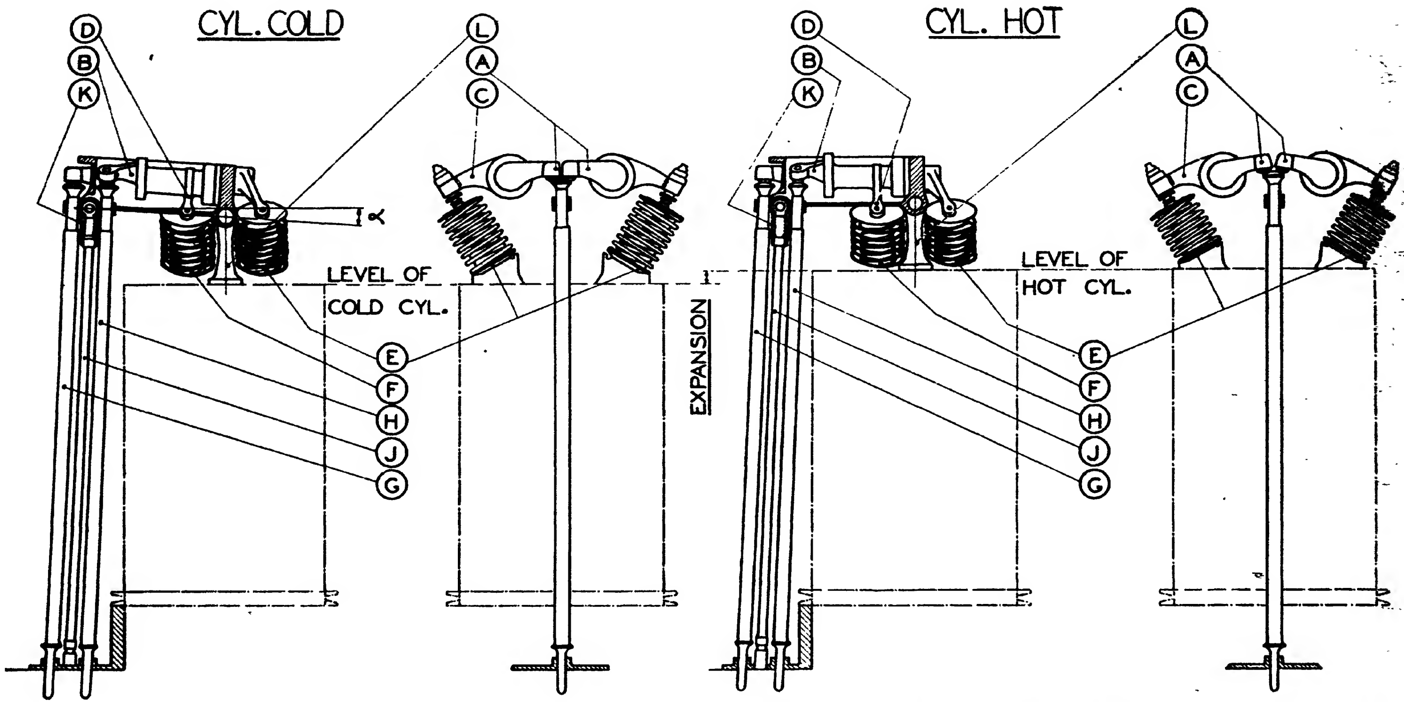


Fig. 10.—Rocker Gear—Dismantled.

A push rod cover holder is secured to the underside of the rocker bracket by two spring loaded set screws, whilst immediately behind it is an air deflector. To prevent the push rod cover from rising, two felt pads are cemented to the cover flange. On later engines the two felt pads are replaced by a single pad.

Valve Clearance Compensating Device.—As previously explained, the rocker gear is supported at three points and is free to move in an outward or inward direction along the centre line of the cylinders. This design was adopted owing to the fact that, at working temperature, the cylinder expands and becomes elongated, but the push rods remain almost constant in length, and therefore, if the rocker gear were rigidly fixed to the cylinder, the valve clearance would be rendered excessive. The com-



Position of Rocker Bracket.

Position of Inlet Rocker Arms (Exhaust Rockers omitted for Clearness).

Angular Displacement of Rocker Bracket due to Cylinder Expansion.

Angular Displacement of Inlet Rocker Arms due to Cylinder Expansion.

A. Inlet Push Rod Lever.
B. Exhaust Push Rod Lever.
C. Inlet Rocker Arm.
D. Exhaust Rocker Arm.
E. Inlet Valve.
F. Exhaust Valve.
G. Inlet Push Rod.
H. Exhaust Push Rod.
J. Tie Rod.
K, L. Rocker Bracket Pivots (Front and Rear).

Fig. 11.—Diagram of Valve Clearance Compensating Device.

pensating gear is designed to obviate this variation and accomplishes its purpose by maintaining the distance between the front end of the rocker assembly and the crankcase practically constant by means of the tie rod, thereby leaving the clearance virtually unaffected. Reference to Fig. 11 will explain the operation diagrammatically.

Cam and Layshaft Gear.—The cam gear assembly is of straightforward construction. Keyed to the front half crankshaft is a crank-

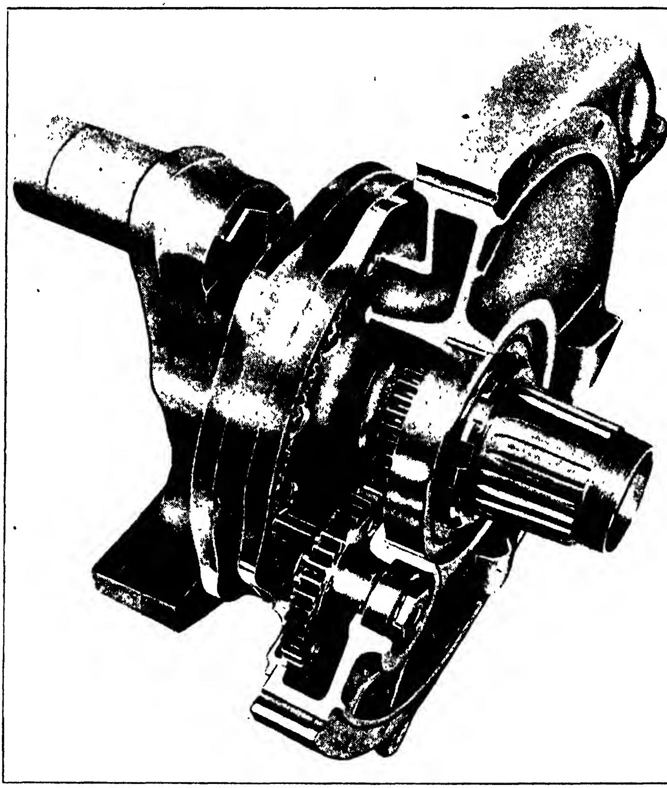


Fig. 12.—Cam Gear showing Method of Driving Cam Sleeve.

shaft sleeve, the bore of which is white-metalled. Upon this rotates (in the opposite direction) a cam sleeve provided with bushes. The cam sleeve is provided with two cam tracks on its outer periphery, each of which has four lobes ; the front row operating the inlet valves and the rear the exhaust valves. Machined round the inner circumference of the flange, formed by the cam track, is an internal spur gear. This gear meshes with the layshaft, which is supported in two roller bearings, one mounted in the front cover, as previously stated, and the other in a housing attached to the cover. Splined to the centre of the layshaft is the layshaft gear, which is driven by the cam drive gear, located in the crankshaft and driven

through serrations on the end face of the crankshaft sleeve. These serrations permit a fine adjustment for valve timing.

The speed of the cam sleeve is 1/8th crankshaft speed in the opposite direction of rotation to the crankshaft. See Fig. 13.

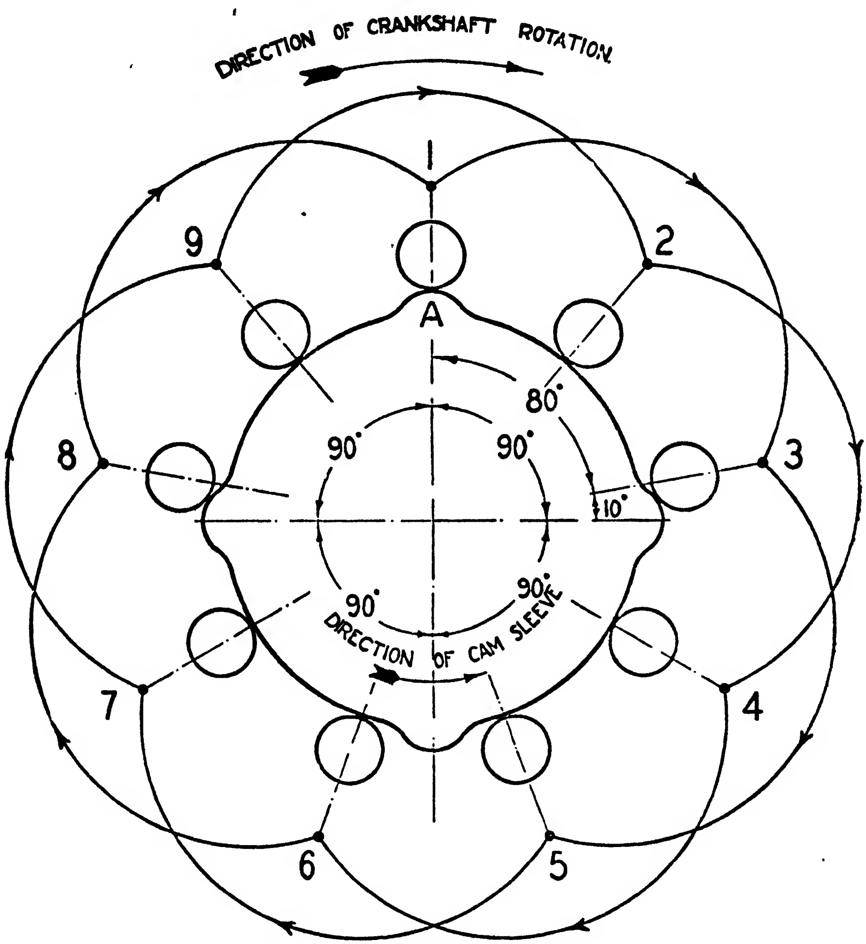


Fig. 13.—Diagram showing Sequence of Cam Operation.

Tappets and Tappet Guides.—Nine pairs of tappets, working in guides, for operating the push rods, are mounted radially around the cam chamber. The tappets are hollow and are slotted at their inner ends to receive the case hardened steel rollers, these rollers being fitted with phosphor bronze floating bushes which rotate on pins. The tappets on cylinders Nos. 4, 5, 6 and 7, which are the lower cylinders, differ from the remainder in that they are each provided with a sleeve, sweated to the spigot behind the head, to prevent over-oiling. The tappet guides are flanged at their

outer ends and are each located in the housings bored in the crankcase as previously mentioned; the inner ends being located in a magnesium alloy ring projecting from the crankcase wall. Rubber rings, located in recesses machined around the tappet guide housings in the crankcase, are provided to prevent oil leakage. As in the case of the tappets, the bottom tappet guides fitted to cylinders Nos. 4, 5, 6 and 7 differ from the top guides in that the diameter of the centre portion is larger in order to accommodate the sleeve on the tappet.

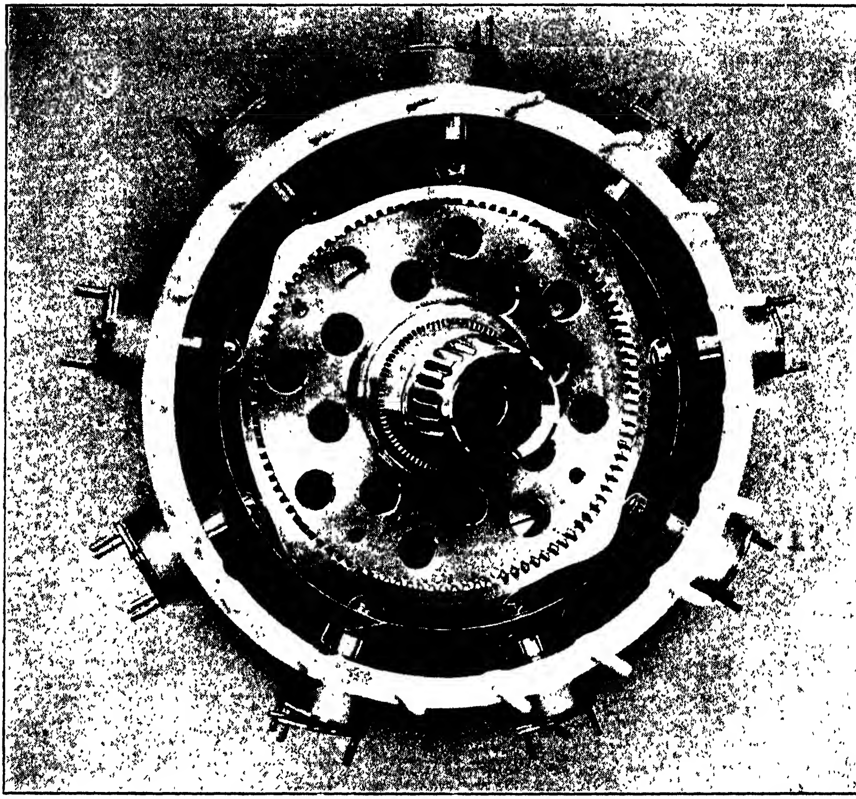


Fig. 14.—Tappets and Guides in Position in Crankcase.

Precision oil seals are fitted in recesses machined in the outer ends of the guides, in order to prevent oil leakage under running conditions.

Reduction Gear.—Reference to the Leading Particulars will show that the reduction gear ratio differs according to the type of engine. Basically, the gears are the same in as much as they are of the self centralising bevel epicyclic type, the ratios available being 0·5 : 1, 0·666 : 1, 0·572 : 1 and 0·655 : 1. The chief differences are the number of teeth in the front and rear bevel gears and the angle of the stub arms on the airscrew shaft. Fig. 16 shows this reduction gear in a dismantled state.

The reduction gear provides a speed reduction between the crankshaft

and airscrew shaft, as stated above. It consists primarily of two opposed bevel wheels of which the front one is anchored to the gear casing and the rear one driven by the crankshaft through the medium of a driving member. Three bevel pinions, mounted on equally spaced stub arms radiating from the airscrew shaft, are situated between the bevel gears and engage both. These pinions rotate on floating bushes, the end thrust being taken by a ball bearing mounted on the outer end of each stub arm.

The rotation of the crankshaft with its bevel wheel, causes the stub arms and, therefore, the airscrew shaft, to be carried round at reduced speed. Equal distribution of the load over the three pinions is achieved by forming spherical sectioned seatings on the bevel wheels to seat on corresponding thrust rings, thereby providing floating mountings that permit the bevel wheels to compensate for any irregularities of the load on the pinions.

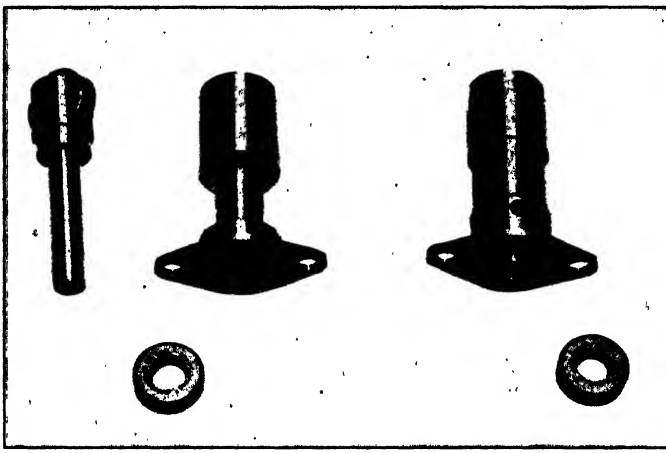


Fig. 15.—Tappets, Tappet Guides and Oil Seals.

The airscrew shaft is carried at the front end in a ball bearing, which serves the dual purpose of a journal and thrust bearing, whilst the tail of the shaft runs in a white-metal bearing in the bore of the crankshaft.

Principle of Operation.—The principle on which the reduction gear operates is shown diagrammatically in Fig. 17.

0·5 : 1 Reduction Gear.

Let A be the fixed bevel gear.

Let B be the intermediate bevel pinion with its axis X.

Let C be the driving bevel gear.

Then, in order to find the movement of X relative to C, let the whole unit be turned through one revolution. Since, however, A is a stationary gear it must be moved back through one revolution keeping X fixed ; this will cause C, which has the same number of teeth, to move one revolution more, making two revolutions in all.

Upon considering the relative movements of the gear (bearing in mind the initial movement of the unit) it will be seen that :—

A is fixed;
X moves through 1 revolution;
C moves through 2 revolutions;

showing that X has half the speed of C or a final speed ratio of 0·500 : 1.

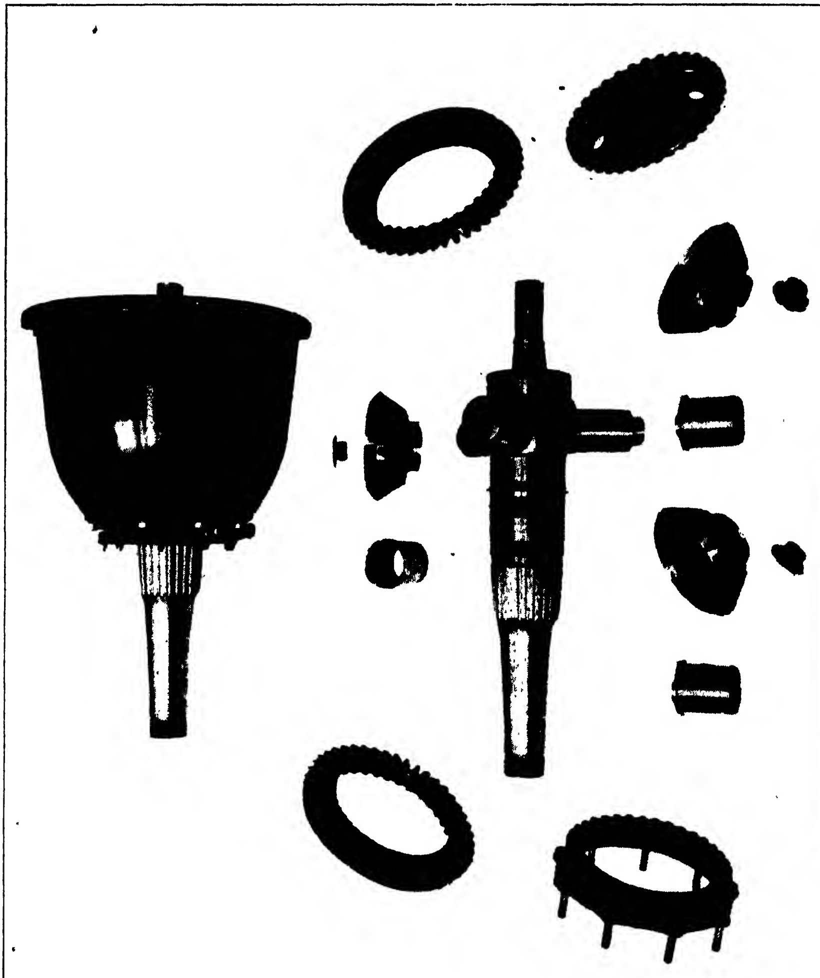


Fig. 16.—Reduction Gear—Dismantled.

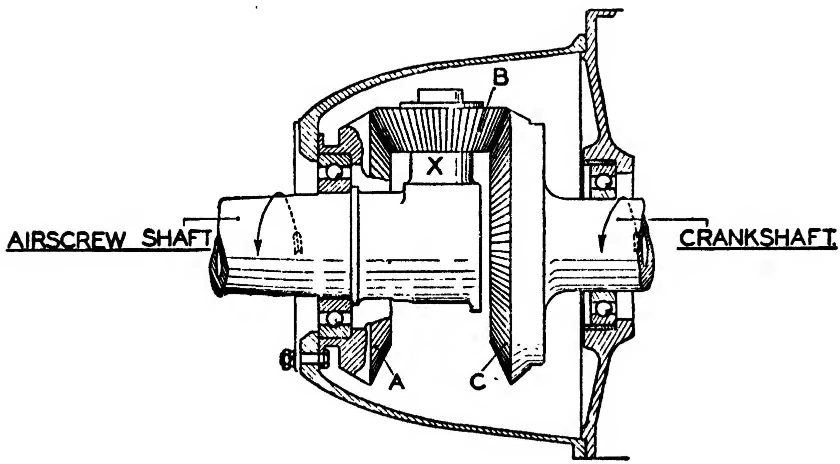
0·666 : 1 Reduction Gear.—Applying the foregoing to the 0·666 : 1 reduction gear. In Fig. 17:—

Let A′ be the fixed bevel gear.
Let B′ be the intermediate bevel pinion with axis X′.
Let C′ be the driving bevel gear.

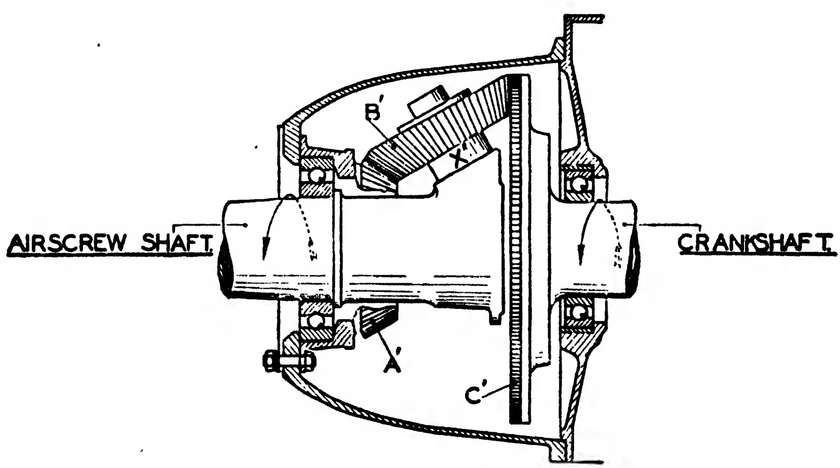
Now move the unit through one revolution. Since A′ has half the number of teeth of C′, one revolution of A′, keeping X′ fixed, will cause half revolution of C′. Therefore the final relative movement will be :—

A′ is fixed ;
X′ moves through 1 revolution ;
C′ moves through $1\frac{1}{2}$ revolutions ;

thus giving a speed ratio of X′ to C′ of 2 to 3 or 0·666 : 1. It will be seen



0·5 : 1 REDUCTION GEAR.



0·666 : 1 REDUCTION GEAR.

Fig. 17.—Diagram showing Principle of Operation of Reduction Gear.

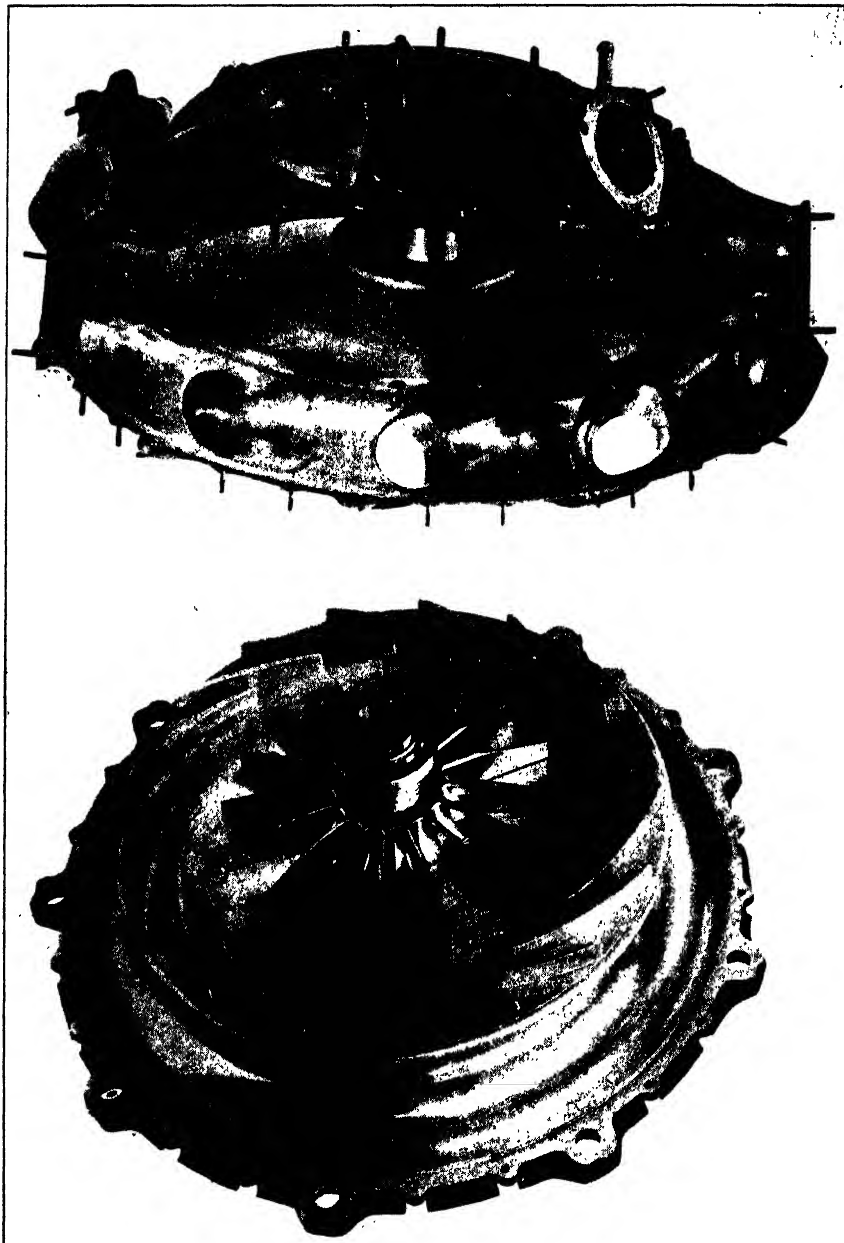


Fig. 18.—Supercharger, Volute Casing and Blower Casing.

that the number of teeth in the bevel pinion has no effect on the speed ratio; which is determined by the ratio of the number of teeth in the fixed bevel to that in the driving bevel. Referring again to Fig. 17, application of the above shows that rotation of the crankshaft with its bevel gear C′ will cause the bevel pinion B′ to rotate on its axis X′ around the fixed gear A′, carrying the airscrew shaft, which is integral with X′, around with it at reduced speed.

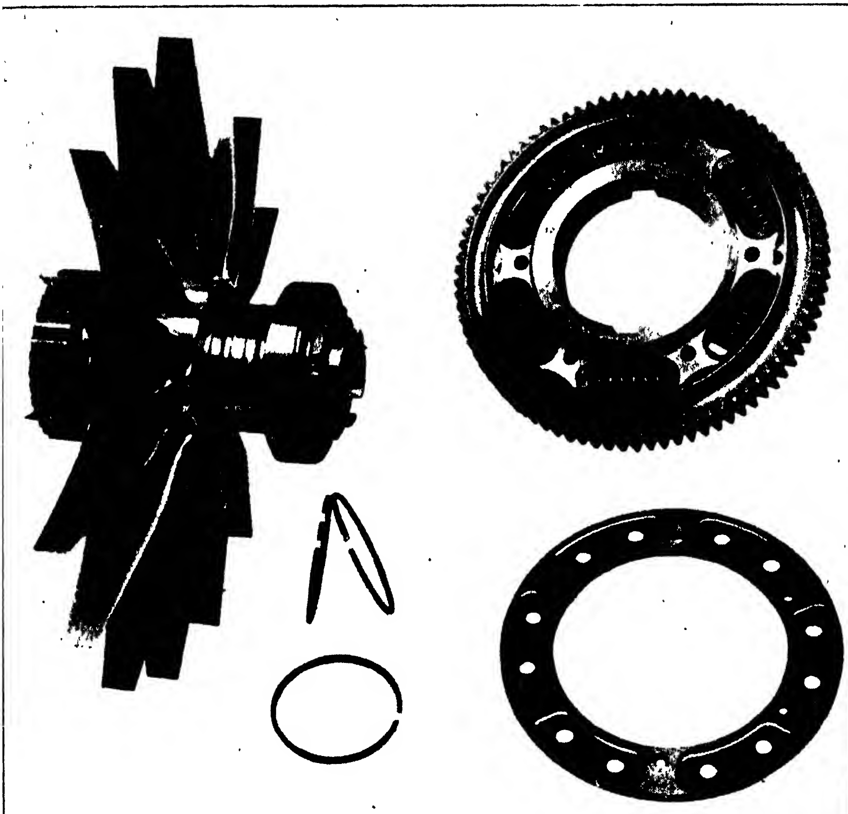


Fig. 19.—Supercharger Impeller and Spring Drive.

Variable Pitch Airscrew Oil Control Supply.—From Pegasus X onwards provision is made for operating variable pitch airscrews by means of oil. The supply is taken from the main engine system and fed by pipe line from a control valve, mounted on the rear cover, to an oil transfer housing on the front of the reduction gear casing. A certain number of engines have the control valve mounted in the transfer housing. Oil, on entering the transfer housing, is fed through a radial hole in the hollow airscrew shaft. This is accomplished by means of a rotating oil seal.

Supercharger.—Unlike the motor-car which is supercharged for the purpose of increasing the power on the ground, the aero-engine is super-

charged, primarily, in order to retain the power at altitude, although later series, from Pegasus X onwards have more power for take-off. The supercharger fitted to these engines is of the gear driven centrifugal type, the unit being located in the induction system between the carburettor and the engine. The mixture is drawn from the carburettor to a volute casing, whence it is delivered by the impeller, which rotates concentrically around the crankshaft tail shaft, through the vaned diffuser, to the annular induction system. On Pegasus II. to VIII. the diffuser is a separate unit, whilst on later engines it is machined integral with the blower casing.

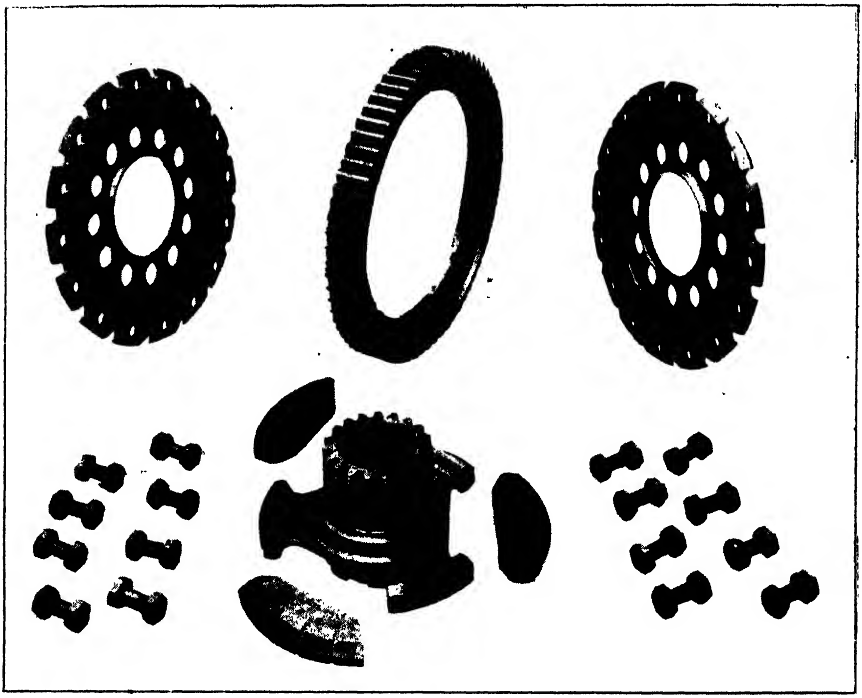


Fig. 20.—Supercharger Clutch Drive—Dismantled.

From this chamber the mixture is delivered through nine tangential induction branch pipes, each of which supplies one inlet pipe of adjacent cylinders ; thus there are eighteen induction pipes, or two per cylinder. With this arrangement the incoming gases are cooled more effectively and the volumetric efficiency improved.

The initial drive for the blower is by means of a spring drive gear mounted on the crankshaft rear half, immediately behind the rear main bearing ; it is driven through two keys. The torque is transmitted from the centre dogs to the intermediate gear through the medium of six stiff springs located by T shaped pads, the purpose of the spring drive being to damp out cyclic variations. This gear drives three intermediate pinions which, in turn, through the medium of " wedge " section clutch blocks,

drive the intermediate gears. This system of clutches limits the torque transmitted and allows slip in the case of rapid acceleration and deceleration. The intermediate gears drive the steel impeller through the medium of the impeller gear and provide the second and final stage in the gearing, thus giving the blower ratio necessary according to the type of engine. In the case of the Pegasus II-L, the ratio of which is 5·7 : 1, only one intermediate gear is fitted ; in addition, the impeller in this type is made from a light alloy and has webs between each blade for strength.

Rear Cover.—The rear cover is an alloy casting secured to the volute casing by studs and nuts, a rubber ring making an oil seal between the two.

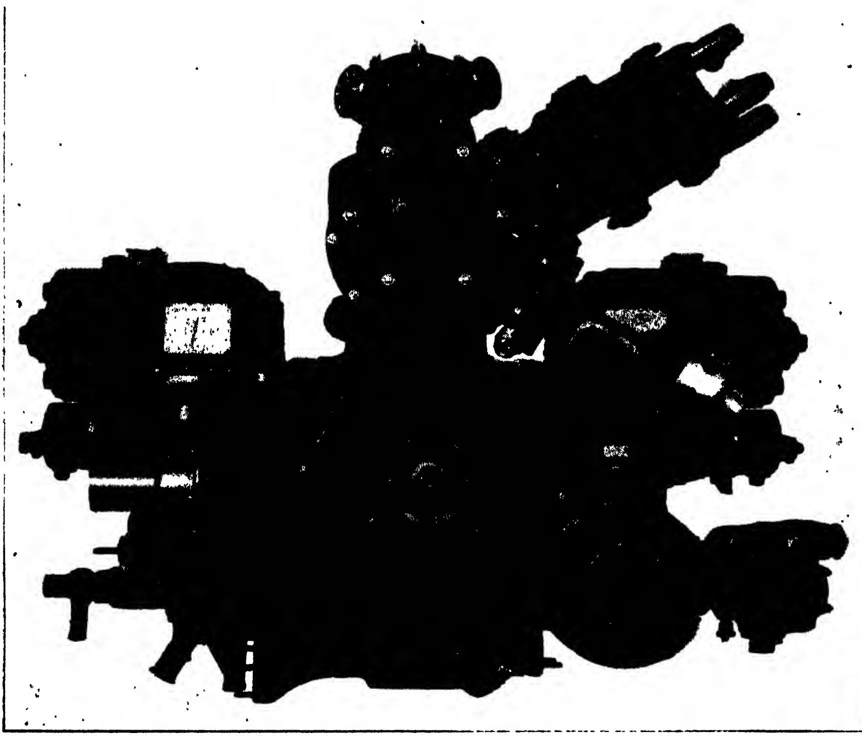


Fig. 21.—Rear Cover, showing Magnetos, Air Compressor, Starter, Fuel Pump and Gun Gear, in Position.

The list of auxiliaries detailed below is of those available for fitting to the rear cover, but it will be appreciated that all cannot be fitted at the same time. The units are chosen by the aircraft constructor to suit the individual installation. The magnetos and oil pump are of course fitted as standard on all series, although they may differ in type.

Magnetos.
Oil Pump.
B.T.H. Type A.V.—A. Air Compressor.
Fuel Pump: Single, Direct or Flexibly Driven (the latter on Pegasus II.-VIII. only).

Dual Fuel Pump.
Starter: Inertia or Turning Gear (Hand or Electric).
R.A.E. Air Compressor or Romec Vacuum Pump.
Automatic Advance Gun Gear or Continental Gun Gear.
Gun Gear, non-automatic (Pegasus II.-VIII. only).
Rotoplunge pump, if gun gear not fitted.
Electric Generator drive, Flexible or Bulkhead.
Tachometer drive.
Gas Starter Distributor (Pegasus II.-VIII. only).
V.P. Airscrew Control Valve. (Late Pegasus X. and onwards).

A boss in the centre of the front wall of the casting is bored to accommodate the tail shaft bearing. Immediately above this the wall is bossed up to take the flanged fixed spindle of the magneto drive gear, whilst above this again there is another boss for the gun gear shaft bush. The upper part of the casing is formed into a square housing in the top of which is an aperture to accommodate the gun synchronising gear, or Rotoplunge pump, whilst the rear of this housing is bored and faced to form a four stud mounting for the auxiliary drive casing. The casing houses the drive for the electric generators, and also carries the R.A.E. air compressor or Romec vacuum pump. On Pegasus engines, before series X, a gas distributor for engine starting is fitted, suitable pipes being taken from the distributor to a non-return valve in each cylinder. Below this casing, and co-axial with the crankshaft tail shaft, is a six stud facing to which is attached the inertia starter. If not required, the aperture is blanked off with a cover. Mounted transversely on the rear cover are the two magnetos. On the port side of the starter housing is a machined face for carrying the automatic throttle control, passages being drilled through the rear cover to connect with the main oil supply for operating the control.

On the port side of the rear cover at the top, is the V.P. airscrew oil control valve, whilst on the same side, but below the magneto, is the oil pump housing. Suitable oilways are machined and cored in the casting for serving the pump. On the starboard side of the rear cover, opposite and in line with the oil pump housing, is a six stud facing to accommodate the cross drive housing and A.V. compressor drive casing. On engines up to series VIII, the A.V. air compressor drive is replaced by a bevel gear and housing for driving the flexibly driven fuel pump, or a driving sleeve if the direct drive fuel pump is fitted. On the rear of the cover, and below the centre line of the cross drive housing, is a bored facing to accommodate the revolution indicator drive housing. At the bottom of the cover, extending from front to rear, is a coarse mesh oil filter, whilst on the starboard side of the filter is the main oil feed union.

Oil Pump Unit.—This gear-type oil unit consists of a pressure pump and a scavenge pump, the latter having a greater capacity than the former in order to ensure a dry sump when running. Both sets of gears are housed in casings having suitable ports machined in them, which line up with the oil passages in the rear cover housing. The drive for the oil pump is taken from the cross drive shaft, which is in turn driven at engine speed by spiral gears from the crankshaft tail shaft. The teeth of the driving pump gears are chamfered on the leading side, and the driven gears on the trailing side, to prevent oil being trapped and thus setting up undue pressure. These

gears are increased in length on later engines, in order to cope with the increased oil circulation. To prevent flooding of the lower cylinders when

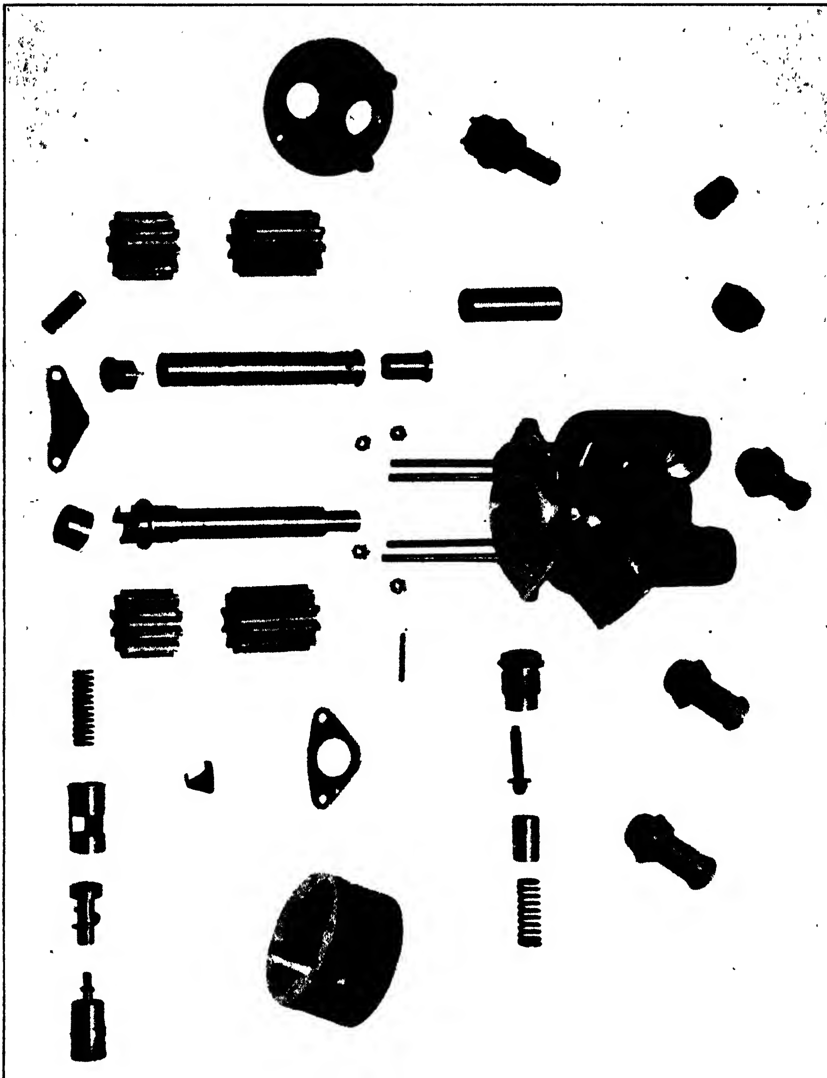


Fig. 22.—Oil Pump—Dismantled.

the engine is standing, in aircraft having an oil tank with a positive head, a spring loaded check valve is fitted. On engines after series VIII., provision is made for safe-guarding the engine against oil starvation during the first few minutes of running. This consists of a High Initial Oil Pressure

device incorporated in the oil pump. The device automatically increases the oil pressure to the bearings and at the same time supplies oil to an

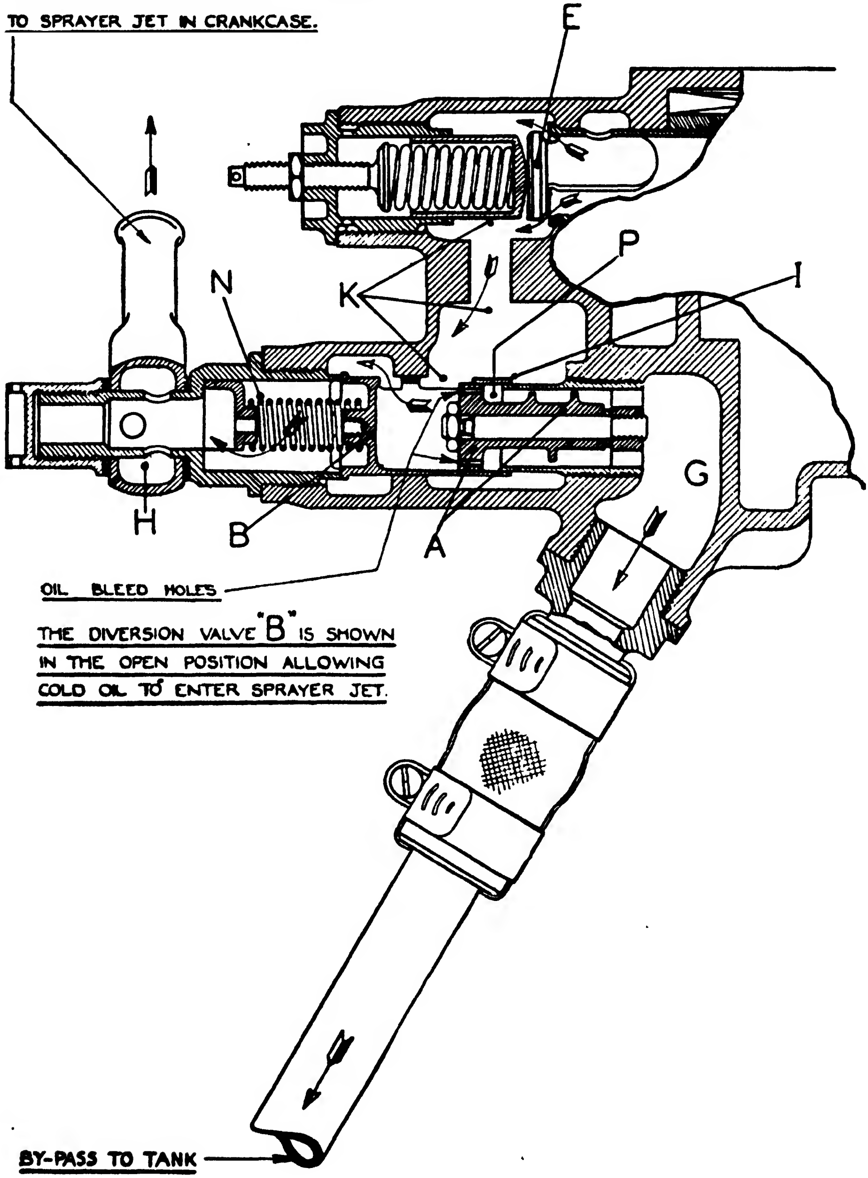


Fig. 23.—Diagram showing Oil Pump High Initial Oil Pressure Device.

auxiliary jet, mounted in the top of the crankcase and so positioned that a supply of oil is directed on the connecting rod assembly and thus splashed

around the interior of the crankcase and over the pistons and cylinder walls. The high initial oil pressure device assists in raising the oil temperature to the operational figure very rapidly, and as the temperature rises, the initial oil pressure falls until the normal working temperature is attained, when the device goes out of action.

The principle of operation is as follows (see Fig. 23) :—

When starting the engine with cold oil in the system, the standard pressure will be exceeded, and will consequently lift the relief valve " E." The oil, on passing through the chamber " K," will endeavour to pass the port " I," through the restrictor "A" and thereby reach the chamber " G " and return by pipe to the tank. Owing to the resistance offered to the cold oil by the restrictor "A," sufficient pressure is built up in the chamber " K " to open the sprayer valve " B " and thereby close the port to the restrictor "A." The by-passed oil now flows through the sprayer valve, into the cap " H " and thence through a pipe, to the jet mounted on the crankcase. When the oil inlet temperature reaches approximately 30°C. to 35°C., the temperature in chamber " K " will decrease owing to the freedom with which the hot oil passes through the restrictor bleed holes; thus the valve " B " will be slowly closed by the spring " N " thereby uncovering the port " I " and allowing the hot oil to pass through the by-pass chamber " G " and pipe line to the tank. On certain series, the by-passed oil is returned to the suction side of the oil pump.

Rear Cover Auxiliary Drives.

Magneto Drive.—Integral with the starter jaw mounted on the crankshaft tail shaft, is a spur wheel which drives a single intermediate gear at engine speed. The drive is transmitted through six helical springs to a bevel gear driving two other gears, which are at right angles to, and disposed one on each side of it. See Fig. 24. Each of these in turn drives a magneto, through the medium of the driving drum and the automatic advance and retard coupling at 9/8th engine speed. On Pegasus Series II to VIII, the driving drums are flanged and have two slots, each of which

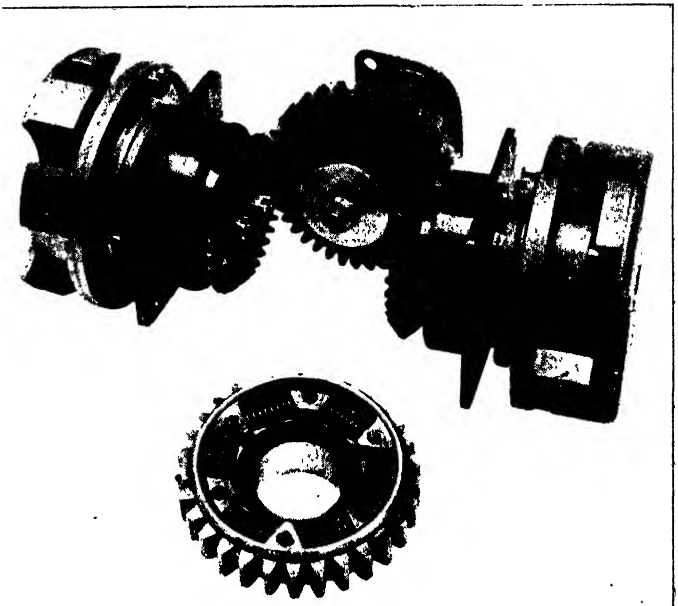


Fig. 24.—Magneto Driving Gears showing Spring Drive Gear.

engages a steel coupling. These couplings have serrations machined on their outer face which mesh with similar serrations on the magneto spindle coupling. The serrations permit of a very close magneto timing. The automatic advance and retard couplings are not fitted to these early engines.

Gun Gear.—Accommodated on the housing at the top of the rear cover above the magneto drive is the automatic cam advance gun gear, or in the case of Pegasus II. to VIII. the fixed type gear. A gun gear shaft, with integral bevel gear, is driven from a spur gear on the starter jaw through the magneto intermediate gear. The forward end of the shaft is supported in a bush in the rear cover, whilst the rear end is carried in a bush housed in the auxiliary drive casing; the shaft projecting into the drive casing, and carrying an auxiliary drive pinion keyed on the extreme end, thus providing axial location.

Rotoplunge Oil Pump.—Should a Rotoplunge oil pump be fitted in place of the gun gear, the driven bevel is carried in ball bearings located in

a housing spigoted to the aperture in the top of the rear cover. The pump is carried on an adaptor fitted between the housing and the pump; the drive being transmitted through a square sectioned spindle. If neither of these auxiliaries be required, the drive is blanked off with a cover plate.

Romec Vacuum Pump.—If required, a Romec vacuum pump may be fitted on the pump drive housing, which in turn is retained to the auxiliary drive casing at an angle of 52° above the horizontal. An integral driven bevel and shaft, supported in two ball bearings carried in the drive housing, meshes with an integral driving bevel on an auxiliary drive shaft, which is driven from the gun gear shaft and transmits the drive to the pump. The auxiliary drive shaft runs in two ball bearings, the front end being located in a plain bush. The inner bearing is retained in the inner wall of the drive casing by a circlip, the outer bearing finding its own location in a bronze sleeve carried in a housing which is sandwiched between the generator drive casing and the end cover.

R.A.E. Air Compressor.—The R.A.E. air compressor replaces the Romec vacuum pump. When the compressor is fitted, the complete drive housing, detailed above, is removed and substituted by the compressor drive. The driven bevel is supported in a double row ball bearing, carried in a separate housing, and drives the compressor through the internally splined integral shaft.

Electrical Generator Drive.—In order to provide current for radio and other electrical apparatus, two types of generator drive are available for fitting to these engines:—

(*a*) the Flexible Shaft type in which the length varies to suit the installation; and

(*b*) the Cardan Shaft type which is a direct and considerably shorter drive, having a flexible coupling incorporated at each end.

The drive for the generator is taken from a driving bevel wheel keyed on the auxiliary drive shaft. A description of these drives is as follows:—

(*a*) **Flexible Drive.**—Driven by the bevel mentioned above and at right angles to it, is an integral bevel and drive shaft mounted on roller and ball bearings, the latter taking the thrust. From this point the torque is transmitted by a square-ended flexible shaft which is supported in a flexible, rubber covered, steel casing. A collar protects the end of the drive and also forms the end location for the flexible casing. At the generator end, the flexible shaft is sweated and screwed to the shaft end, which is located in a ball race housed in the generator drive housing. It is then reduced to square section and engages a coupling.

An external oil drain from the driving end of the unit is required only when the drive is positioned below the horizontal centre line of the auxiliary drive shaft.

(*b*) **Cardan Shaft Drive.**—An integral driven bevel and hollow shaft is mounted on a ball and a roller bearing carried in the bearing housing. The universal shaft end passes through the hollow shaft and is driven by the squared bore at the upper end and retained in position by a split pinned nut. Bolted to the universal shaft end, and to the cardan shaft, is a flexible coupling, whilst a similar flexible disc is secured to the lower end of the cardan shaft and to the laminated spring drive, which engages with the dog keyed to the generator armature shaft; the drive is totally enclosed in a quickly detachable aluminium guard tube.

An external oil drain from the bearing housing is required when the drive is positioned below the horizontal centre line of the auxiliary drive shaft.

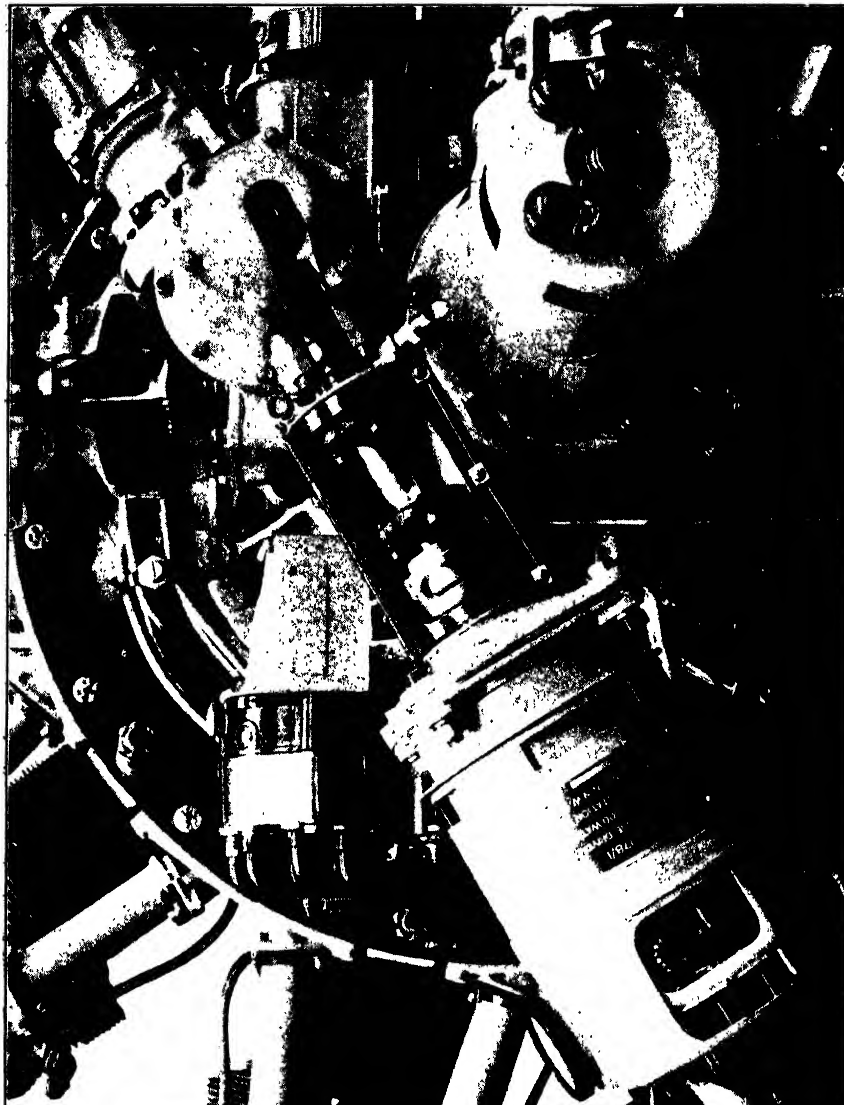


Fig. 25.—Rear Cover, showing Generator and Cardan Shaft Drive.

The gear ratio between the drive shaft and generator driving unit, varies with different series of engine, consequently in no circumstances should the driving units be interchanged between engine types, unless the

correct gears have first been fitted. This is necessary owing to the importance of keeping the generator speed within specified limits.

Cross Drive Shaft and Tachometer Drive.—The cross drive shaft is supported at one end in a plain bearing and at the other in a ball bearing, the ball bearing being carried in the cross drive housing. The inner race of this bearing is axially located between a lip on the shaft and the sleeve of the revolution indicator drive gear, which is drawn up by a lock nut. The outer end of the cross drive shaft is internally splined to receive the compressor drive coupling.

B.T.H. Air Compressor and Fuel Pump Drive.—Mounted on two ball bearings in the compressor drive casing, is the compressor drive shaft, having an integral bevel wheel. The inner bearing is carried in the compressor drive casing and axially located by a retaining ring; the inner race being drawn up by a nut against the bevel wheel. The inner race of the outer bearing is retained longitudinally against a shoulder by a circlip and finds its own location on its housing. The bevel wheel, previously mentioned, meshes with the compressor-driven bevel, which is mounted in a ball bearing carried in a housing secured to a flange on the inside of the drive casing. The splined extension of the compressor crankshaft mates with the internal splines of the driven bevel which transmits the drive. (See p. 250).

A dumb-bell oil connection is provided to carry the oil from the hollow cross drive shaft to the compressor drive shaft.

When the compressor is not required, a cover is substituted and a ball bearing, housed in the cover and retained by a circlip, is used to steady the outer end of the driven bevel shaft.

The outer end of the compressor drive shaft is internally splined to receive the dual fuel pump driving gear; a dumb-bell oil connection being fitted to carry the oil from the shaft to lubricate the pump.

When a single fuel pump is fitted, or the drive is blanked off, an oil thrower and coupling unit is fitted to the shaft end.

Direct Driven Fuel Pump.—A dual fuel pump can be fitted direct on the rear cover; the drive being transmitted through the internal splines on the cross drive shaft to the splined pump driving gear. If, however, a single fuel pump is fitted, or the drive is blanked off, an oil thrower and coupling is fitted to the shaft end.

Fuel Pump (Dual).—A dual fuel pump comprises two complete and independently acting vane type pumps, in one body, with common suction and delivery ports. Spring loaded isolating valves are provided between each pump and a common outlet on the pressure side to prevent loss of pressure in the event of one pump failing.

Fuel delivery pressure in each half of the pump is adjusted and controlled separately by adjustable relief valves. Separate pressure gauge connections are also provided. The main driving gear meshes with and drives two pump spindle gears, which transmit the drive through shear pins to the two pumps. Spring loaded glands are provided on each spindle to prevent leakage of fuel. Lubrication is by pressure through suitable oil holes to flats on the driving shafts and pump spindles.

The single fuel pump is basically similar to the dual pump, but has only one vane type pump embodied. As in the case of the dual pump, suitable glands are provided and a relief valve incorporated.

Automatic Cam Advance Gun Gear.—The adoption of three bladed airscrews and high engine speeds has necessitated the introduction of the automatic advance gun gear from Pegasus X onwards, in order to provide

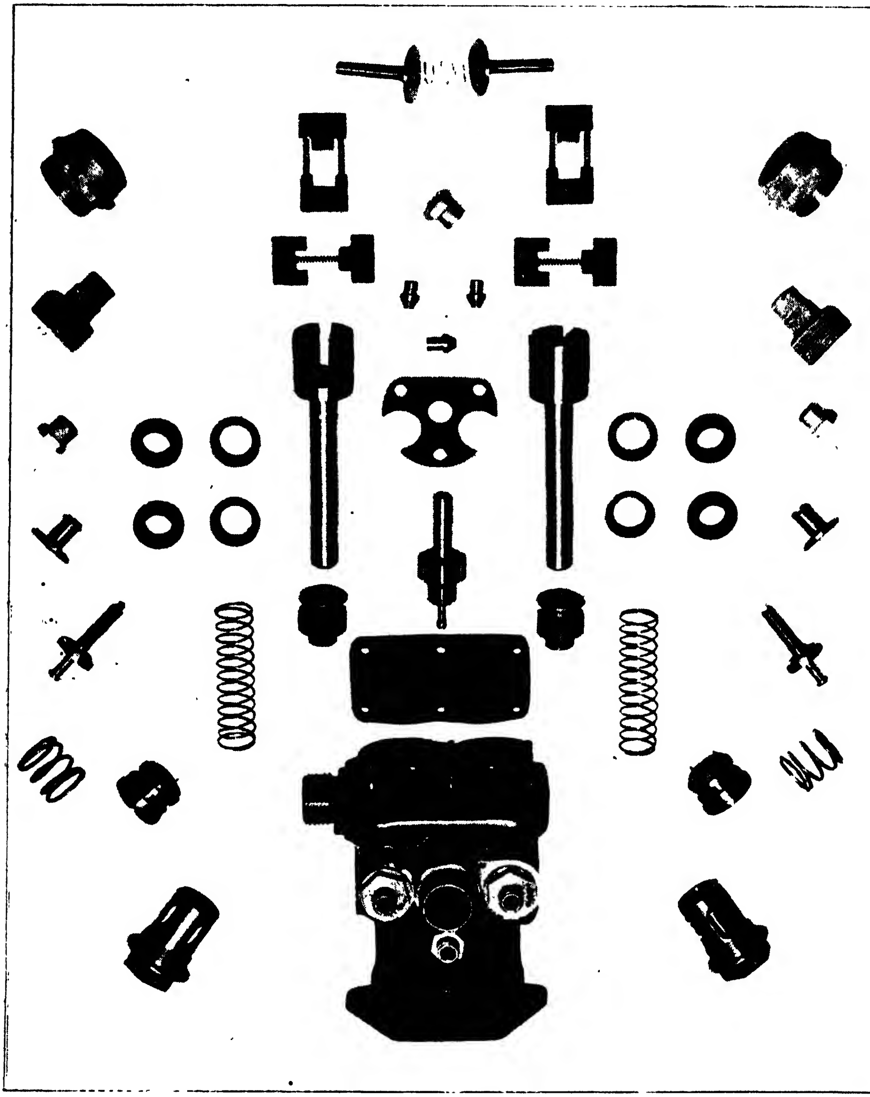


Fig. 26.—Dual Type Fuel Pump—Dismantled.

a more flexible type of synchronising control. The smaller angle between the blades of a three blade airscrew as compared with a two blade airscrew, requires a more exact synchronising device as the airscrew speed rises, due to the firing period lagging out of phase.

This is achieved by a centrifugal governor which advances the cams as the speed rises and thus eliminates the possibility of the airscrew being hit.

The governor unit is mounted on ball bearings housed in a vertical casing; the two cams being fitted to the upper part of the shaft. The splined bevel wheel shaft transmits the drive to corresponding splines on the outer sliding sleeve, the drive then being taken through helical splines to the cam shaft, at the upper end of which are attached the trunnions for

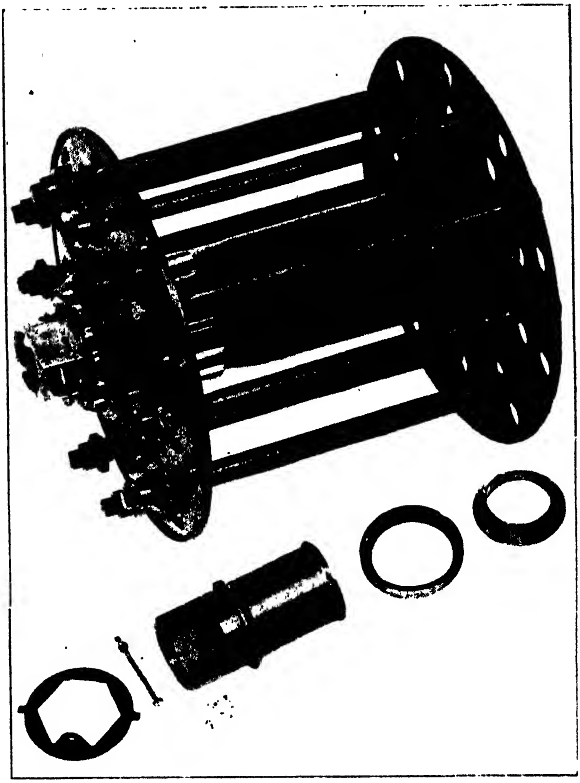


Fig. 27.—Hub for Wood Airscrew showing Locking Device.

the top links of the governor weights. The lower links are connected to a thrust bearing arranged to lift the splined sleeve against a compression spring.

When in operation, the governor weights take up a position determined by the centrifugal force and the load exerted by the spring. The movement of the sleeve on the splines causes the cam shaft to rotate relative to the drive shaft, by an amount depending on the position of the weights and the angle of the helical splines. The relative movement or advance of the cams therefore depends on the speed of rotation.

Lubrication is provided by splash from the gun gear drive shaft.

The automatic advance gun gear must at all times be treated as a complete unit and must be fitted to and removed from the engine as such and should not, in any circumstances, be dismantled.

Airscrew Hub for Wood Airscrew.—A twelve bolt airscrew hub, to accommodate a wood airscrew, is normally used on engines prior to Pegasus X. It consists of two main parts, the hub and the front flange.

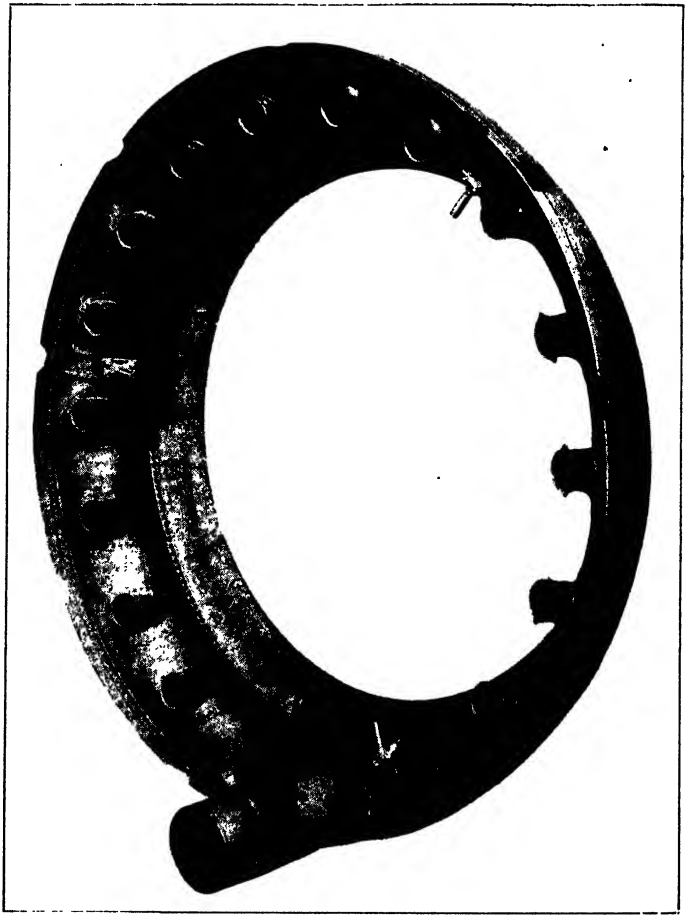


Fig. 28.—Single Outlet Exhaust Ring (Large Diameter).

The base of the flange is stiffened to form a boss, in the bore of which tapered splines are machined to engage with corresponding splines on the airscrew shaft. At the front end of the hub, splines are cut on the outside circumference to receive the correspondingly splined hub flange. The hub is mounted on the taper splines of the airscrew shaft and retained by a nut which, when screwed on to the shaft, bears against a conical collet and transmits the pressure to the airscrew shaft.

Exhaust Ring.—The exhaust ring is situated at the front of the engine,

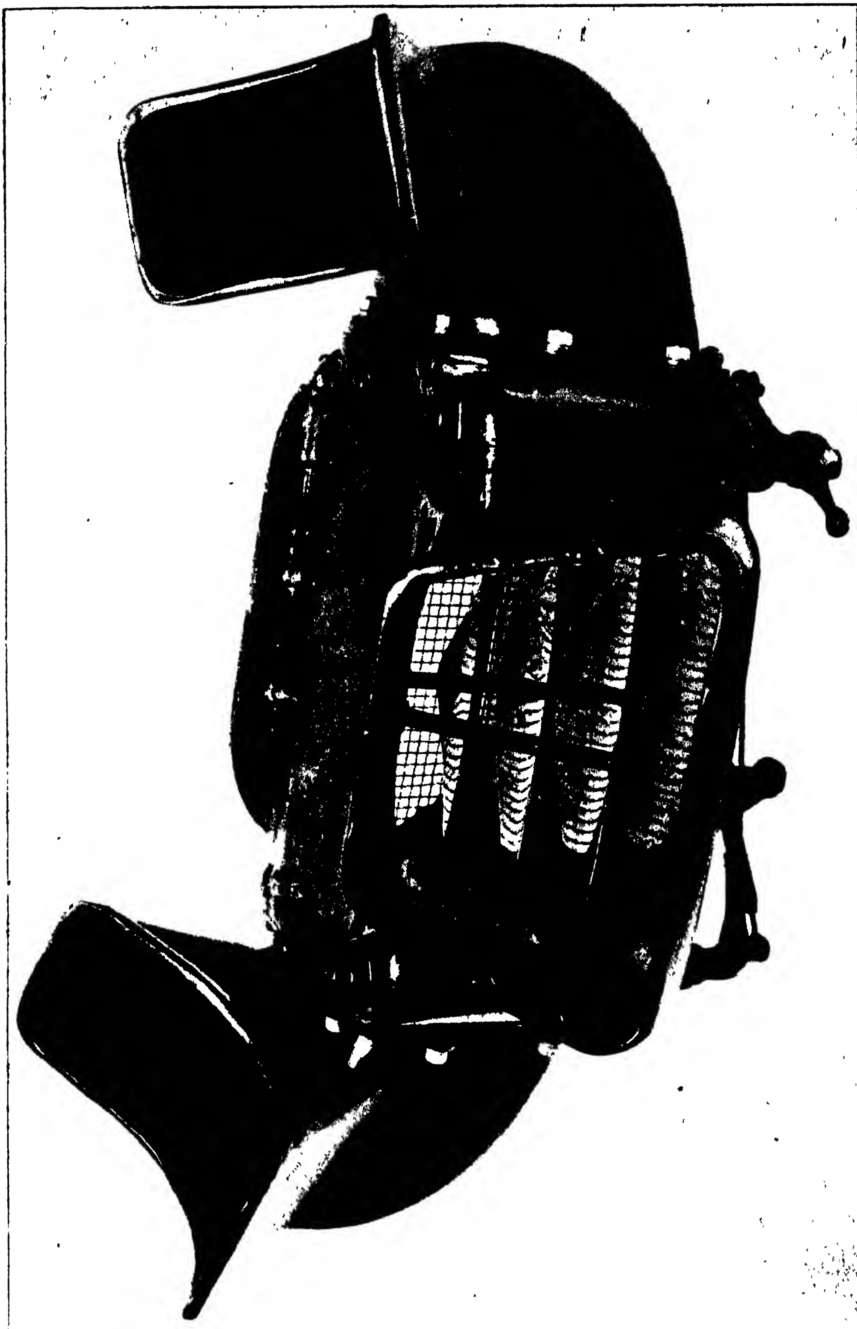


Fig. 20.—Air Intake

around the reduction gear casing, and is mounted by means of three tripods rigidly fixed to the crankcase front cover, the apex of each tripod being connected to the ring by brackets, through the medium of flexible rubber mountings. The exhaust ring is made from two steel pressings of such shape as to form the leading edge of the cowling. On earlier Pegasus engines the shape is of approximately streamline section and much smaller in diameter than the later type. The supports differ also, in as much as they are steel pressings and have Ferodo discs to secure the ring brackets by frictional grip, the clearance holes being sufficiently large to allow for any expansion during running. The flexible mounting unit of the later engines is so designed that it forms a sliding joint, thus permitting expansion of the ring when hot.

The eighteen branch pipes from the cylinders to the ring are provided with universal sliding joints.

A 6-inch diameter tail pipe is riveted to the body of the ring at approximately two-thirds inside and one-third outside the cowling line, or, if required, two D section pipes can be fitted in approximately the same position.

Air Intake.—A common air intake is provided having three air inlets, of which the central one admits air at atmospheric temperature, whilst those on either side admit air which has been preheated by passing over the cylinder heads of cylinders Nos. 5 and 6. The centre one forms the main body of the air intake and is a light alloy casting.

Spring loaded shutters enable either warm or cold air to be admitted; the spring returns the shutters to the unheated air position. The heated air position being obtained by operation of the control lever in the cockpit by means of suitable interconnections. The spindles are hollow and lubrication of the bearings is provided for by a nipple at one end of each spindle.

Controllable Gill Cowl Assembly.—In order to obtain better control over the cooling air, a controllable gill cowling is fitted to all engines after Pegasus VIII. This cowl is only suitable for use with the large diameter exhaust ring and the long chord cowling. The cowling is an extension to the exhaust ring and is built up in panels which are easily detached, by means of quick release fasteners, for examination of the rear of the engine and installation generally. At the rear of this cowling and forming an extension, are the controllable gills; they are adjustable from the pilot's cockpit, so that the air exit gap can be adjusted to suit flight requirements. It consists of a number of hinged sections carried on a support ring, which in turn is anchored to the cylinder head; provision being made for differential expansion and vibration. The gills are operated by means of an endless chain passing over sprockets; one for each gill. The sprocket bosses are each provided with an internal square thread, in which works a threaded plunger connected to a bell crank lever, upon which the gill panel is attached. The rotation of the sprockets through the medium of the chain, therefore, opens or closes the gills. To prevent chain slack, a suitable tensioning device is incorporated.

The De Havilland Hamilton V.P. Airscrew Control.—As previously stated, Pegasus X. and onwards are provided with a control valve either in the rear cover, or on the reduction gear casing, for operating the V.P. airscrew blades. A three-bladed airscrew is used chiefly, full details of which may be found in the De Havilland Airscrew Service Manual.

The pitch control valve consists of a two position plunger, operated by Arens control cable. The oil supply from the main pressure passage in the rear cover is carried from the valve through rubber jointed steel pipes, and No. 1 crankcase bolt, to the oil transfer housing on the reduction gear casing and thence to the operating cylinder of the airscrew. The released oil from the cylinder when returning to the coarse pitch position, returns through the feed pipe to the rear cover. On those engines with the valve on the reduc-

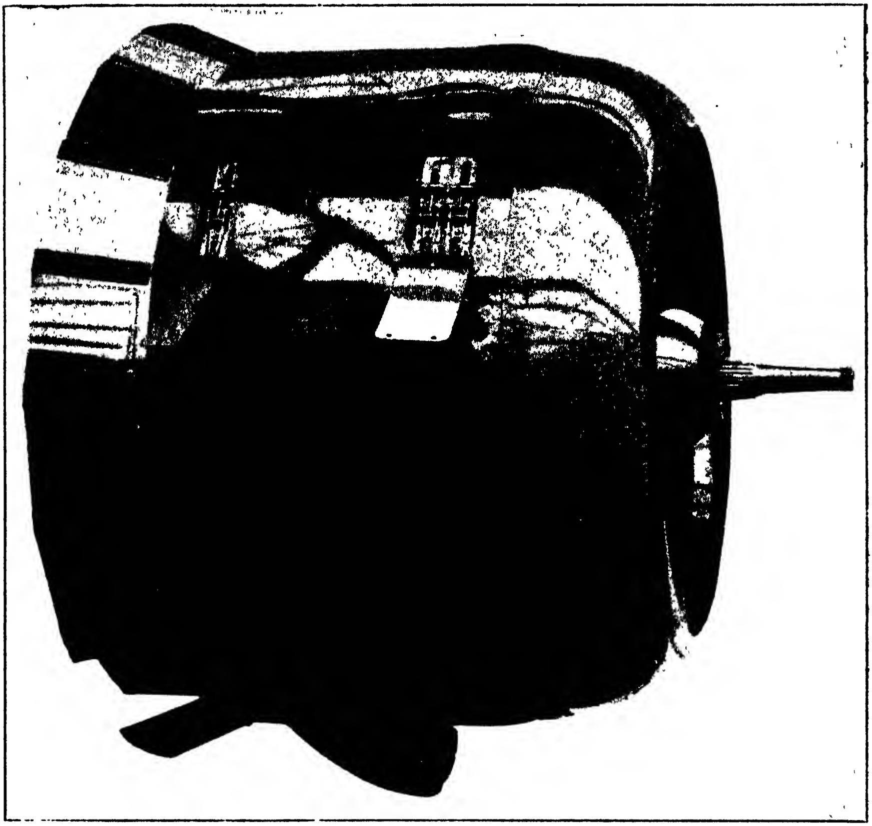


Fig. 30.—Engine Cowling with Controllable Gills.

tion gear casing, the oil is taken straight from the rear cover through a similar pipe and thence via the control valve to the airscrew mechanism. The released oil is drained back into the reduction gear case through a hole drilled in the oil valve casing.

Operation.—When the control valve cable is in tension, the valve is pulled into its outermost position, in which position it cuts off the oil supply between the engine pressure system and the airscrew operating cylinder, thus releasing the pressure and allowing the oil in the cylinder to drain into the sump. The airscrew blades then assume the coarse pitch position under the influence of the counterweights.

With the control cable under compression, the valve is pushed to its inner position which makes a connection between the engine oil pressure system and the operating cylinder, so that the blades are moved to the fine pitch position. On later engines, provision is made for positive lever actuation of the control valve as an alternative to the Arens control cable.

Priming System.—A three cylinder priming system is standardised. The primer pump connection is located on the volute casing, from which branch pipes are led up to a connection on the starboard inlet pipe elbows on cylinders Nos. 1, 2 and 9. For starting in cold climates, a seven cylinder priming system may be fitted. With this system the fuel is delivered to a circular supply pipe, whence radial branch pipes are led up to a connection on the starboard inlet pipe elbows on cylinders Nos. 1, 2, 3, 4, 7, 8 and 9.

Lubrication System.—Reference to Figs. 31 and 32 shows the system of lubrication on these engines. Oil is delivered under pressure to: the crankpin, master rod and big end, articulated rods, cam sleeve bushes, airscrew shaft tail bearing, bevel pinions, supercharger bearings, magneto drive and auxiliary drives. Splash lubrication is provided by oil thrown off or draining from the pressure lubricated components to the following: pistons and gudgeon pin bearings, crankshaft main roller bearings, cam gear and tappets and those parts of the supercharger gear, reduction gears and rear cover drives which are not lubricated by pressure.

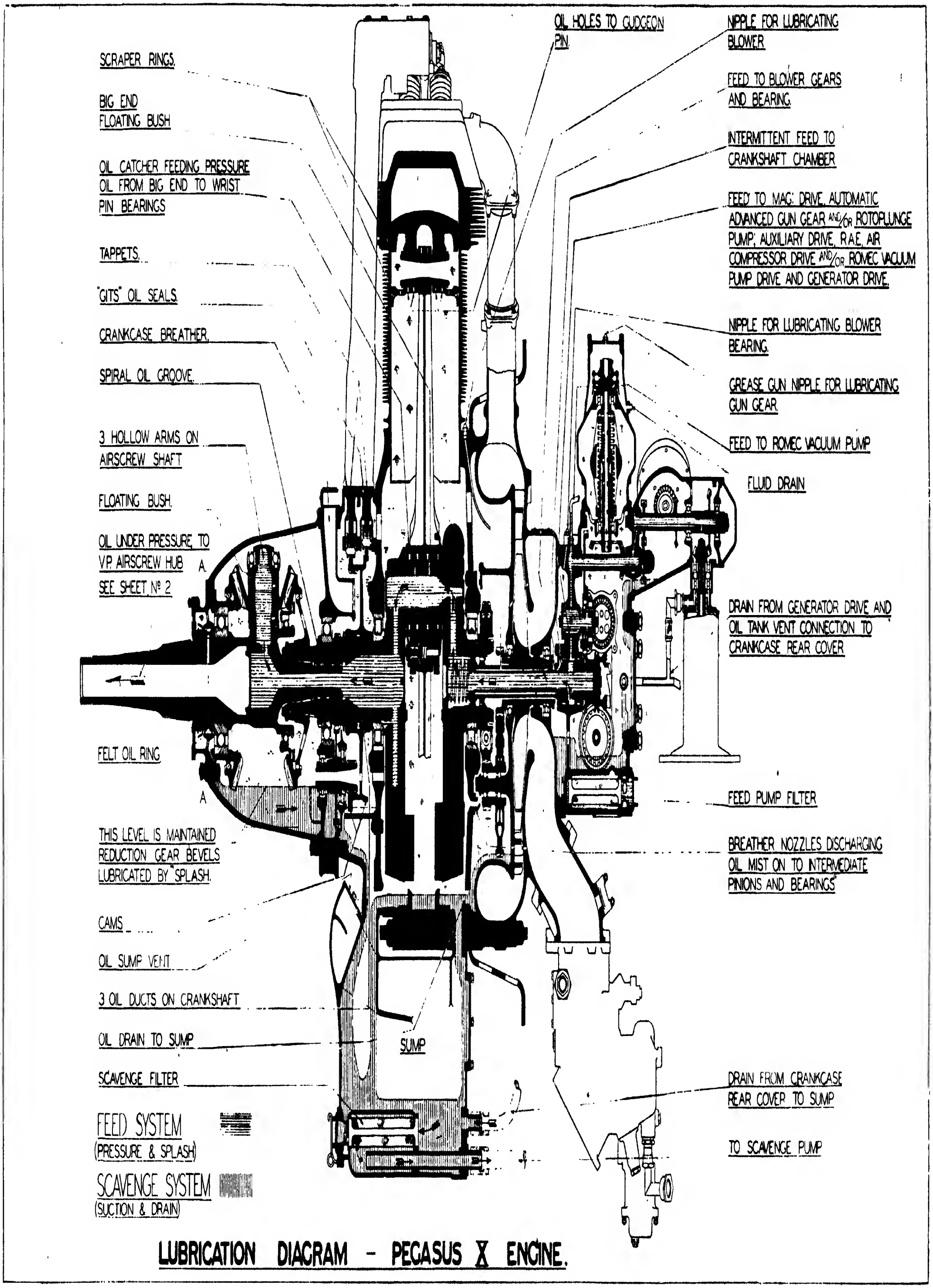

SCRAPER RINGS.
BIG END FLOATING BUSH
OIL CATCHER FEEDING PRESSURE OIL FROM BIG END TO WRIST PIN BEARINGS
TAPPETS.
"GITS" OIL SEALS.
CRANKCASE BREATHER.
SPIRAL OIL GROOVE.
3 HOLLOW ARMS ON AIRSCREW SHAFT
FLOATING BUSH.
OIL UNDER PRESSURE TO V.P. AIRSCREW HUB SEE SHEET Nº 2
A
FELT OIL RING
A
THIS LEVEL IS MAINTAINED REDUCTION GEAR BEVELS LUBRICATED BY SPLASH.
CAMS
OIL SUMP VENT
3 OIL DUCTS ON CRANKSHAFT
OIL DRAIN TO SUMP
SCAVENGE FILTER
FEED SYSTEM (PRESSURE & SPLASH)
SCAVENGE SYSTEM (SUCTION & DRAIN)
OIL HOLES TO GUDGEON PIN.
NIPPLE FOR LUBRICATING BLOWER
FEED TO BLOWER GEARS AND BEARING.
INTERMITTENT FEED TO CRANKSHAFT CHAMBER
FEED TO MAG: DRIVE, AUTOMATIC ADVANCED GUN GEAR AND/OR ROTOPLUNGE PUMP; AUXILIARY DRIVE, R.A.E. AIR COMPRESSOR DRIVE AND/OR ROMEC VACUUM PUMP DRIVE AND GENERATOR DRIVE.
NIPPLE FOR LUBRICATING BLOWER BEARING.
GREASE GUN NIPPLE FOR LUBRICATING GUN GEAR.
FEED TO ROMEC VACUUM PUMP
FLUID DRAIN
DRAIN FROM GENERATOR DRIVE AND OIL TANK VENT CONNECTION TO CRANKCASE REAR COVER
FEED PUMP FILTER
BREATHER NOZZLES DISCHARGING OIL MIST ON TO INTERMEDIATE PINIONS AND BEARINGS
SUMP
DRAIN FROM CRANKCASE REAR COVER TO SUMP
TO SCAVENGE PUMP
LUBRICATION DIAGRAM - PEGASUS X ENGINE.

Fig. 31.

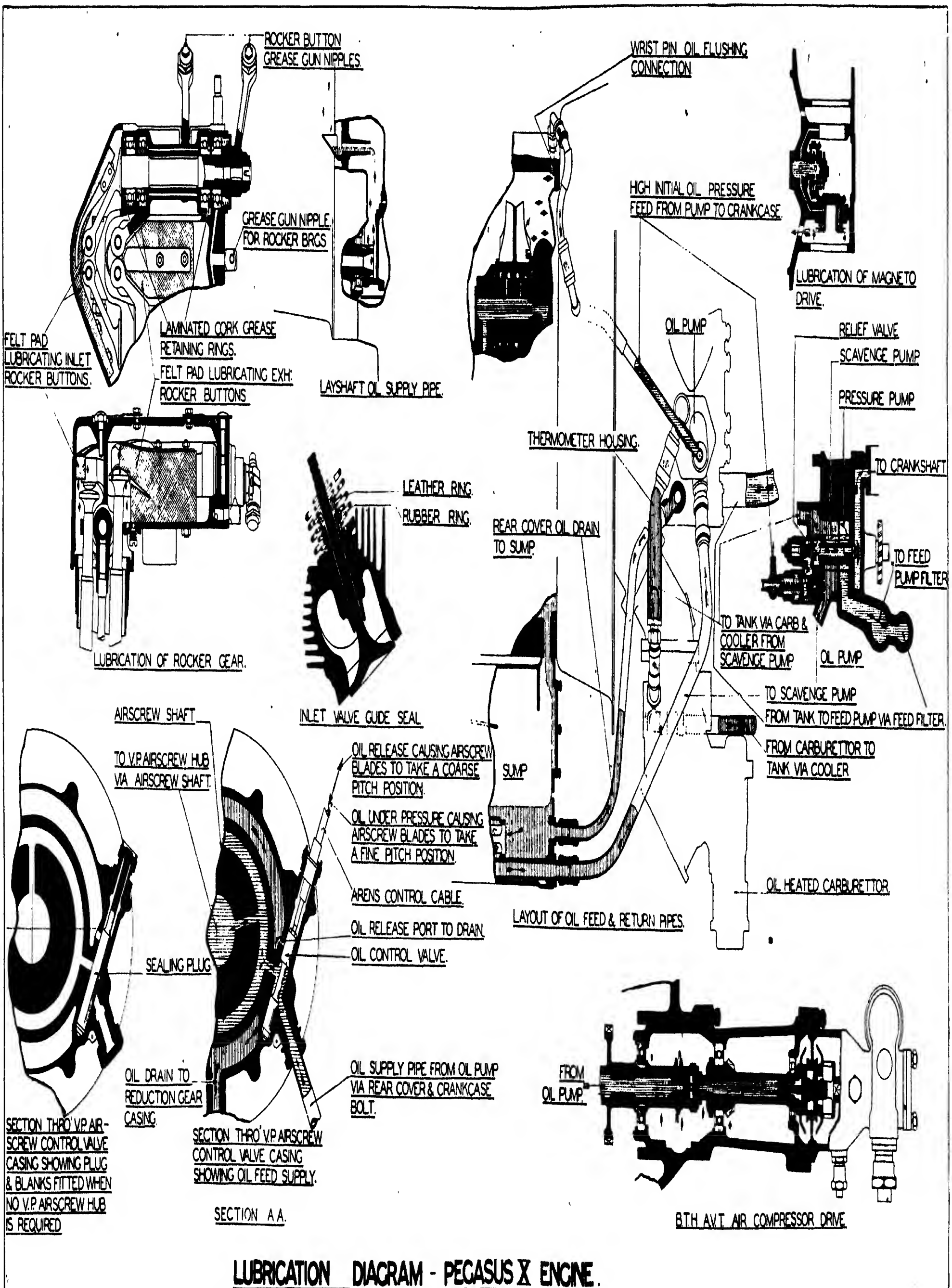

ROCKER BUTTON GREASE GUN NIPPLES.
GREASE GUN NIPPLE FOR ROCKER BRGS
LAMINATED CORK GREASE RETAINING RINGS.
FELT PAD LUBRICATING INLET ROCKER BUTTONS.
FELT PAD LUBRICATING EXH: ROCKER BUTTONS
LAYSHAFT OIL SUPPLY PIPE.
LUBRICATION OF ROCKER GEAR.
LEATHER RING.
RUBBER RING.
INLET VALVE GUIDE SEAL
WRIST PIN OIL FLUSHING CONNECTION.
HIGH INITIAL OIL PRESSURE FEED FROM PUMP TO CRANKCASE.
LUBRICATION OF MAGNETO DRIVE.
OIL PUMP
THERMOMETER HOUSING.
REAR COVER OIL DRAIN TO SUMP
RELIEF VALVE
SCAVENGE PUMP
PRESSURE PUMP
TO CRANKSHAFT
TO FEED PUMP FILTER
TO TANK VIA CARB & COOLER FROM SCAVENGE PUMP
OIL PUMP
TO SCAVENGE PUMP
FROM TANK TO FEED PUMP VIA FEED FILTER.
FROM CARBURETTOR TO TANK VIA COOLER
SUMP
OIL HEATED CARBURETTOR
LAYOUT OF OIL FEED & RETURN PIPES.
AIRSCREW SHAFT
TO V.P. AIRSCREW HUB VIA AIRSCREW SHAFT.
OIL RELEASE CAUSING AIRSCREW BLADES TO TAKE A COARSE PITCH POSITION.
OIL UNDER PRESSURE CAUSING AIRSCREW BLADES TO TAKE A FINE PITCH POSITION.
ARENS CONTROL CABLE.
OIL RELEASE PORT TO DRAIN.
OIL CONTROL VALVE.
SEALING PLUG
OIL DRAIN TO REDUCTION GEAR CASING.
OIL SUPPLY PIPE FROM OIL PUMP VIA REAR COVER & CRANKCASE BOLT.
SECTION THRO' V.P. AIR-SCREW CONTROL VALVE CASING SHOWING PLUG & BLANKS FITTED WHEN NO V.P. AIRSCREW HUB IS REQUIRED
SECTION THRO' V.P. AIRSCREW CONTROL VALVE CASING SHOWING OIL FEED SUPPLY.
SECTION A.A.
FROM OIL PUMP.
B.T.H. A.V.T. AIR COMPRESSOR DRIVE.
LUBRICATION DIAGRAM - PEGASUS X ENGINE.

Fig. 32.

CARBURETTOR.

The requirements of a modern supercharged engine from a carburation point of view, have called for a considerable amount of advanced design in order to meet the varying conditions imposed upon it. Briefly, the car-

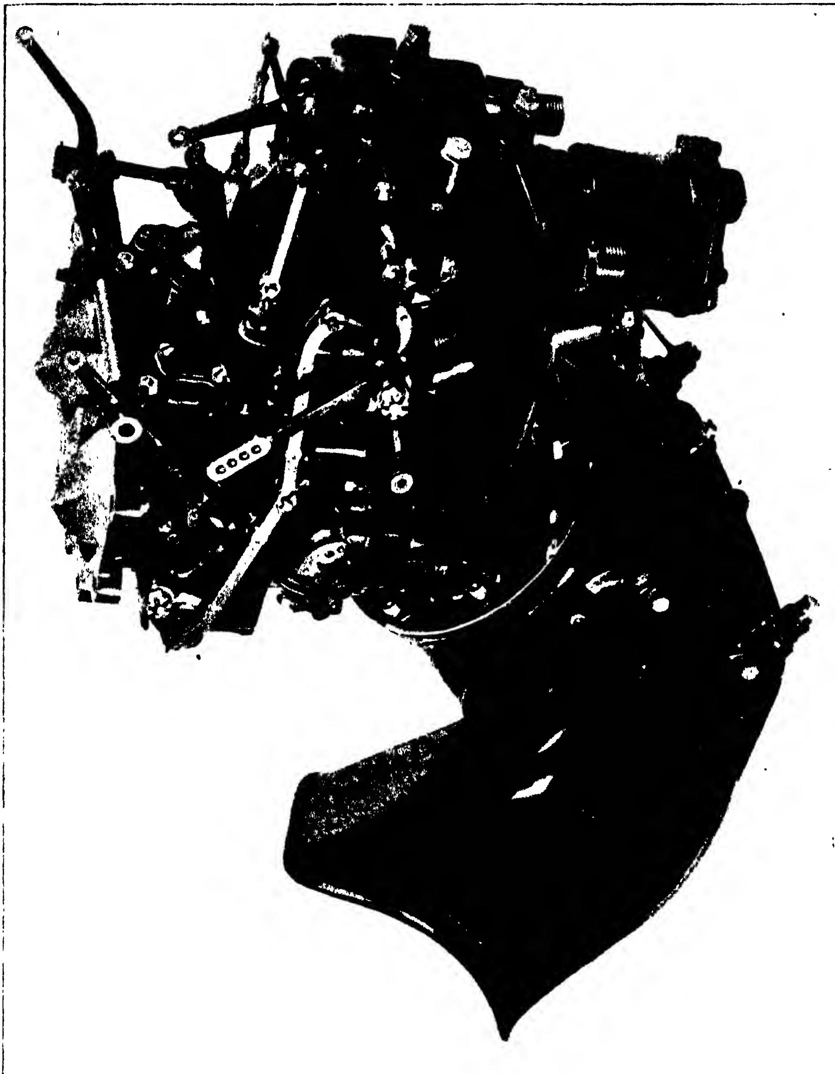


Fig. 33.—Claudel-Hobson Carburettor, Type A.V.T. 85E.

burettor must be satisfactory at all positions of throttle opening, also from the point of view of acceleration and slow-running; capable of being regulated to suit varying pressures at altitude, and finally, but not the least important, provide for economical fuel consumption.

The Claudel Hobson type A.V.T. 85E carburettor is generally used and consists of two complete carburettors in one unit, comprising two choke tubes, two diffusers, two jets and two float chambers, the latter being

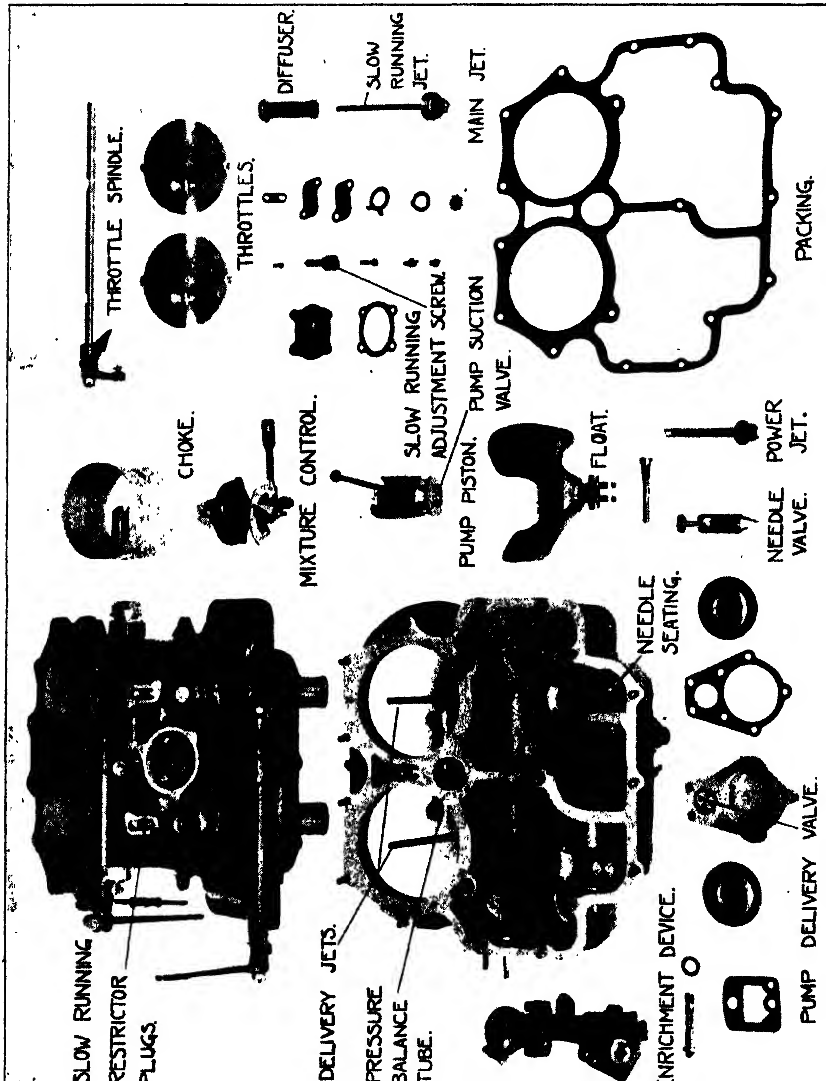


Fig. 34.—Component Parts of Claudel-Hobson A.V.T. 85E Carburettor.

interconnected by a pressure balance system. To compensate for altitude, a common mixture control is provided and is centrally placed above the two. The carburettor is mounted on the intake side of the supercharger unit.

The carburettor body is built up in two halves which meet on the horizontal centre line in a faced flanged joint. The upper half carries the choke tube housings, throttles, throttle housing, the mixture control valve, and the diffuser assemblies, whilst the lower houses the two float chambers, the accelerator pump, the power and enrichment jets, and the pressure balance nozzles.

In order to provide the correct mixture at low speeds, *i.e.* from slow-running until the main jets come into operation, certain special features are incorporated. A passage is drilled transversely across each butterfly throttle, whilst two small holes are also drilled through each throttle into this passage, one being on the upper and one on the under surface.

The slow-running jet tubes, which run up the centre of the diffusers, project into sockets formed behind the centre line of the choke tubes.

The slow-running cut-off valve enters the passage from the outside of the body and provides adjustment for the volume of mixture that passes into the upper part of the passage. Above the valve, the passage enters a small air box closed by a detachable cover plate. Two tapped holes are drilled through the front of the box and break into the choke tube housing; the lower of the two holes enters at a point coincident with the lower edge of the throttle, whilst the upper registers with the slow-running hole. These holes take the two externally threaded restrictor jets.

Principle of Operation.—When idling, the throttle is practically closed and a high depression exists above the throttle. Fuel is flowing from the slow-running jets, but in order to break down the depression slightly, and obtain the correct mixture strength with the throttle in this position, and at the same time to emulsify the fuel admitted, air is allowed to enter via :—

(*a*) a small hole drilled in the slow-running jet tube;
(*b*) the lower air bleed jet; and
(*c*) a small hole in the underside of the throttle.

When the throttle is opened, the transfer passage comes opposite the lower air bleed jet, thus reversing the flow through this jet, which now supplies fuel to the transfer passage and thus to the engine. By this means, a slight additional quantity of fuel is supplied to compensate for the increased quantity of air reaching the engine when the throttle opens. When the throttle is opened a little further, the depression on the slow-running jets, via the air bleed holes, is diminished and the main jet comes into operation; from this point onwards the effect of the air box jets is lessened.

NOTE.—The air bleed jets should not be altered.

Whilst care has been taken to ensure fuel economy under cruising conditions, the carburettor embodies special features to ensure good acceleration and high power for taking off, both of which are accomplished by using a dual accelerator pump, a power jet, and an enrichment jet.

Satisfactory acceleration is obtained by using two pumps; one, interconnected with the throttle control, discharges a small quantity of fuel into the port choke delivery tube while the throttle is being opened, whilst the second, operated by a compression spring, continues to supply a small quantity after the throttle comes to rest.

In order to give an economical fuel consumption whilst cruising, and at the same time provide the mixture strength required for the higher

powers, a power jet is provided. This jet is screwed into the base of the starboard float chamber and obtains its supply of fuel via a spring loaded valve. From this jet, the fuel passes to an open delivery tube in the starboard choke. The valve admitting the supply of fuel to the jet is operated by a cam mounted on the throttle control lever cross shaft.

The enrichment jet, also valve controlled, is incorporated in the port side of the float chamber. This control valve is operated by a cam, interconnected with the boost overriding device in such a manner that it is impossible to use the extra boost, for take-off, without enriching the mixture. This jet delivers fuel to the delivery tube, previously mentioned, which has a calibrated orifice. As the two accelerator pumps are connected to the same delivery tube, a non-return valve is mounted immediately below the enrichment jet, to prevent the fuel from the pumps being forced back through the jet when accelerating with the mixture control in the take-off position.

On later engines, acceleration is improved by separating the accelerator pump system from the enrichment system, the fuel from the former being discharged direct into the port choke through an independent central delivery tube. The enrichment jet non-return valve is not required with this new arrangement.

The slow-running regulating sleeves serve a dual purpose :—

(*a*) to regulate the quality of mixture from the slow-running jets; and
(*b*) a means of stopping the engine instantaneously when desired.

They consist of a small spring loaded valve (previously mentioned) carried in a guide, which is screwed into a passage traversing the slow-running passage. The plunger, the end of which is a sliding fit in the passage, is waisted, and when this section is in line with the slow-running passage, the area is sufficient to give an unrestricted flow : the action of pulling out the plunger, blanks off the slow-running passage and thus prevents any further supply of fuel going to the engine.

A single lever, with a cross bar and the necessary linkage, is supplied on the carburettor to operate these valves, but a control is required in the cockpit to operate this lever ; the valve, being spring loaded, will automatically return to the normal position when the control is released. In order to obtain correct adjustment of the two valves, the starboard connecting link is adjustable for length, whilst on later engines, both links are adjustable.

When carrying out any adjustments to the slow-running sleeves, it is important to ensure that both are moved an equal amount and, also, that after the adjustment has been made, both valves return fully and bear on their respective conical faces, as an air leak at this point will affect the running of the engine.

To compensate for altitude, a mixture control is provided ; this is carried out by manipulating a valve which will admit a controlled amount of air to the emulsion passage, thereby reducing the depression created by the chokes. The hot oil from the engine is used to heat the chokes.

As the throttle and mixture control levers are not interconnected on the carburettor, provision must be made in the cockpit to ensure that the mixture control commences to close with the throttle in accordance with the instruction plate on the carburettor. This precaution is

necessary in order to prevent the possibility of the throttle being opened up after a glide with the mixture control in the weak position.

Carburettor Adjustment.

The carburettors are correctly adjusted and tuned before leaving the engine makers ; the setting will therefore be found the most suitable for general use and should on no account be disturbed unless operating conditions are abnormal. Should any adjustments be necessary, however, the following notes must be adhered to.

Adjusting Slow-running Sleeves and Air Bleed Jets.—The effective range of the slow-running cut-out adjusting sleeve is approximately one turn either way from its original position. Exceeding this range when richening up the mixture will serve no useful purpose, whilst when weakening, it is important to note that adjustment must be made in very easy stages, approximately a quarter of a turn at a time, so as to avoid the possibility of a backfire or a flat spot which may occur at about 800 R.P.M. When setting the slow-running cut-out valves, first allow the port valve to seat fully, then adjust the link work on the starboard valve so that the two are synchronised in the open and closed positions.

Mixture Control Valve.—The valve, which is of the taper barrel cock type, is retained in its seating by a spring. In normal circumstances the valve will maintain good contact with its seating, which is essential for correct functioning of the mixture control and carburettor. Should a leak occur through the cock sticking in its bearing or the retaining screws coming loose, these defects must be corrected.

Dismantling and Assembling.—Should the carburettor not function correctly, it will be found that invariably the trouble is due to the jet being choked with dirt or water, to flooding caused by the dirt, or to wear of the needle valve after long service. Normally the carburettor is practically immune from any other source of trouble ; but in the event of it being necessary to dismantle, the following procedure should be adopted :—

(1) Do not tamper with the diffuser as no useful purpose will be served and the characteristics of the carburettor will be disturbed.

(2) When removing the float chambers, disconnect the accelerator pump link from the pump lever and draw the chambers slightly backwards, when clear of the studs, to prevent the floats from fouling the diffuser housing.

On replacing the float chamber, ensure that the joint washer between the body and the float chamber does not turn up around the chokes, thus making a bad joint.

(3) Make sure the power jet valve does not foul the carburettor body as this will probably result in a bent valve. The removal of the power jet valve assembly also calls for care, as the fouling of the valve stem on the side of the tube spanner that is employed for removing it, may result in a bent needle.

Fitting a new needle must be regarded as a major operation necessitating the return of the engine to the test bed for correct setting ; interference with this valve or its operating cam must be avoided.

Should fuel flow from the power jet valve with the operating cam in the closed position, the cause will probably be found to be due either to

the valve sticking in the guide, or to foreign matter lodged on the valve seat.

(4) In the event of it being necessary to remove the power jet valve operating cam shaft, ensure that the position of the cam is marked before it is removed so that the serrations on the cam and its vernier coupling can be reassembled correctly. This operation should also be regarded as a major one, as the correct setting of this cam can only be obtained on the test bed.

On no account must the cam be set at any other than the original position, as no useful purpose will be served by so doing, and the correct tuning of the carburettor will be disturbed.

See that the joint washer is correctly fitted when replacing the cam unit cover.

(5) Access to the delayed action pump valve and accelerator pump valve is obtained by removal of the delayed action pump cover body from the base of the carburettor, when both pistons and pump discharge valves will be exposed and can be inspected readily for any foreign matter present that might cause obstruction.

Should both the pump valve and the discharge valve leak at the same time, an excess quantity of fuel will be drawn off from the carburettor, causing building-up when slow-running; it is therefore necessary that these valves should make good contact.

The delayed action pump body and cover should finally be fitted with the jointing washers between the joint faces.

AUTOMATIC THROTTLE CONTROL.

Mark XXX.B.

As is generally known, the power of an I.C. engine falls proportionally to the atmospheric pressure, consequently, with an aircraft engine, the power will fall with increase in altitude. In order to maintain constant power up to a greater altitude, a supercharger is fitted to all series of Bristol engines. These engines must not be opened up to full throttle on the ground, as detonation and consequent over-stressing of the components will occur as a result of so doing. In order to prevent the possibility of this happening and at the same time relieve the pilot from manually operating the throttle to obtain the constant induction chamber pressure, an automatic throttle control is fitted to the rear cover and interconnected with the throttle controls. An oil supply and return for operating the servo control mechanism is provided through drilled passages in the rear cover. An overriding device and variable datum control is incorporated.

The control consists of an aneroid type diaphragm assembly carried in a sealed chamber which is in communication, via two pipes, with the induction chamber ; it is sensitive to variations of boost pressure. The bottom end of the diaphragm is linked up with the piston control valve of a servo unit operated from the engine lubrication system. This unit consists of a cylinder, piston, and connecting rod, the latter being pivoted to a knuckle joint in the centre of the throttle toggle links. Downward piston movement, in response to a rise in boost pressure in the induction chamber, will result in shortening the effective length of the toggle links and thus tend to close the throttle, whilst a drop below rated boost will have the reverse effect.

To obtain extra power for take-off, means are provided for overriding the boost control to a small extent and at the same time bringing an enrichment jet into action to prevent detonation. The overriding device consists of a control lever, carried at the top of the throttle control unit, and positioned so that downward movement of its operating lever causes the striker forks to depress the spring holder plate and so depress the diaphragm together with the control valve, to a predetermined setting. This allows oil to be admitted to the underside of the servo piston and thus open the throttle. This condition remains until the increased boost pressure compresses the diaphragm, thus lifting the valve and so reversing the oil flow.

Also incorporated is a variable datum control which permits a progressive throttle response under all conditions. It consists of an operating cam, carried in plain bearings, positioned vertically over the diaphragm ; its operating lever being connected to the throttle datum lever by a link tube. As the throttle is opened, the cam bears on the spring holder plate. With continued throttle travel, the cam gradually depresses the diaphragm, virtually resetting it, until the rated boost is attained with the throttle lever in the fully open position. Hence the throttle lever has progressive control of the engine power at all altitudes and at the same time gives a definite point for the introduction of fuel from the power jet to enrich the mixture and prevent detonation.

The diaphragm comprises an assembly of eight exhausted capsules ; it

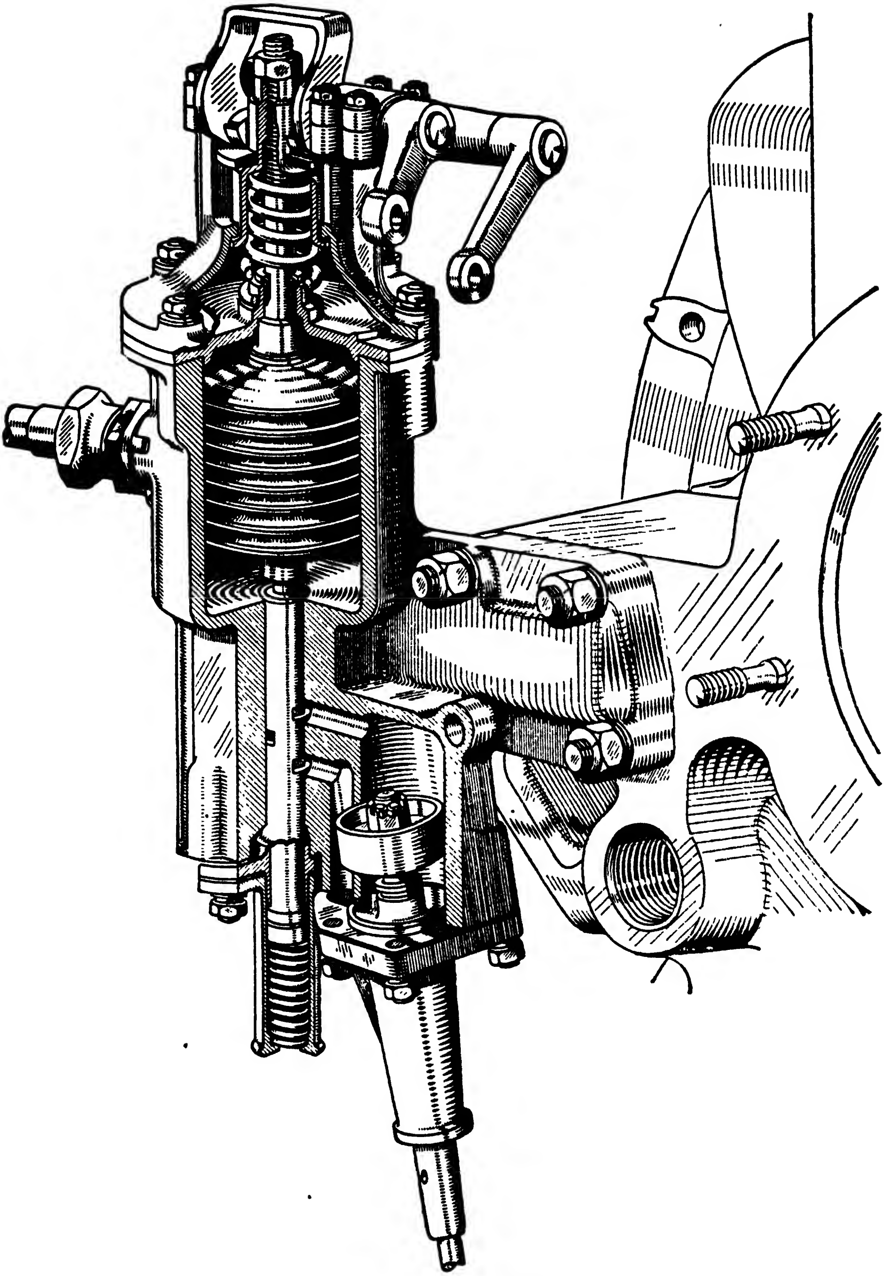


Fig. 35.—Diagrammatic View of Boost Control.

terminates at its upper end in a screwed extension which is secured to the lower end of a screw adaptor. This adaptor projects through a central bore in the control casing cover; the end being screwed into a holder

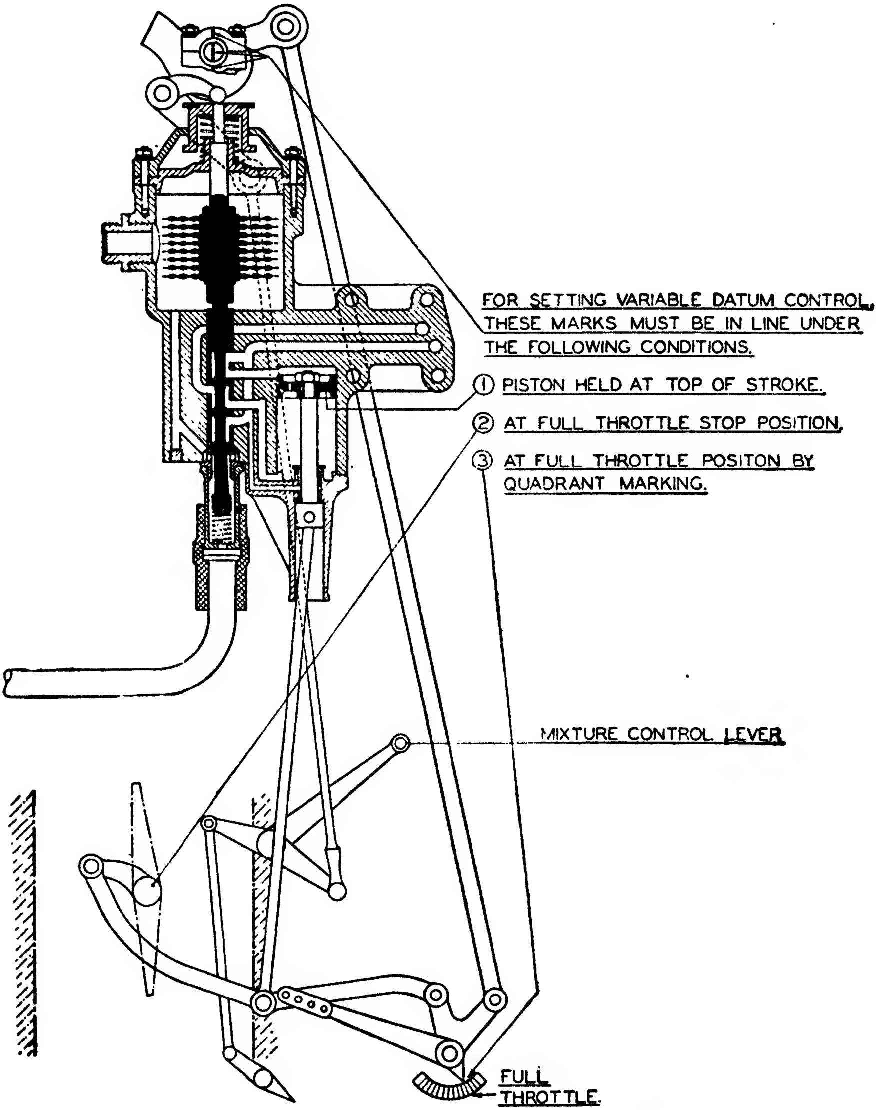


Fig. 36.—Diagram of Boost Control showing Method of Setting.

and projecting through the top for engagement with the override fork and variable datum cam; a spring is interposed between the casing cover and holder. The hollow piston control valve, which works in a steel guide,

is mounted concentrically with the axis of the diaphragm and is attached to it by a ball ended valve link. A cup extension at the lower end of the diaphragm receives the upper end of the link which is secured by a pin. At the lower end, the rod is secured by a pin to the bottom of the valve at 90° to the upper pin. As the rod has a clearance fit in the valve, any slight misalignment can be accommodated. A spring between the bottom of the valve and its cover prevents oscillation.

Two pressure control pipes are connected to the volute casing. An upper pipe leads direct to the diaphragm chamber, whilst a lower pipe, which also acts as a drain, is connected to the control valve cover; this ensures that the pressure is balanced at both ends of the valve.

Formed on the valve are three wide recesses which register with ports in the sleeve and barrel. As shown in Fig. 35, the pressure passage terminates at a port opening into the centre recess of the valve. The transfer ports are equally spaced on either side, as are the two drain ports which are interconnected with a drilled drain passage. The lower transfer port communicates with the chamber on the underside of the servo piston, whilst the upper communicates with the same chamber, but on top of the piston.

With the valve in a central position, the lands on either side of the middle recess close the transfer ports. Downward movement of the valve uncovers both transfer ports, the lower one being fed with oil from the pump, whilst the upper is open to the drain port, consequently the pressure oil will force the piston up. Conversely, upward movement of the valve will reverse the flow and force the piston down.

A piston stop ensures minimum power output of the engine in the event of complete failure of the control.

Setting Control on an Engine.—When the engine is passed off, the linkage is correctly adjusted and sealed, and on no account should the seals be broken except by authorised persons. Consequently the following instructions are only given in order that the operator may correct any discrepancies which might arise, or when new components have been fitted.

The throttle shaft lever should be placed in the fully open position against the stop, and the toggle link lever set at the full throttle position (the pointer should be set on the " F.T." marking on the quadrant plate), and with the servo piston pushed to the top of its stroke, the control connecting rod eye, interconnecting the toggle links, should centre, as illustrated in Fig. 36. If the holes do not coincide, adjust the connecting rod; afterwards wire and seal.

When setting the variable datum cam, the toggle link lever should be set with the pointer on the "F.T." mark on the quadrant, when the scribed line on the port end of the cam spindle should be vertical and in line with the scribed lines on the bearing cap.

Having ascertained that the two rods previously mentioned are correctly set, the control should be adjusted to give :—

(*a*) The rated boost pressure.
(*b*) The take-off boost pressure.

(1) Check boost gauge. Start engine and warm up.
(2) With mixture control lever in the normal position, gradually open the throttle until rated boost is indicated at full throttle.

(3) If, however, the boost is *above* rated value, slow down engine and screw *out* the diaphragm chamber screw adapter until, on opening up the engine, the boost is reduced to the desired figure.

(4) If it is found that the boost is *less*, screw *in* the adaptor screw.

(5) To set the override control, set the mixture control to "rich" or "take-off" position and open the throttle until correct take-off boost is obtained. If the control is correctly set, no further increase in boost pressure should occur when the throttle is opened fully.

(6) Alteration of the take-off boost pressure is made by adjustment of the connecting rod; the rod being *lengthened* to *decrease* the boost pressure and *shortened* to *increase* same. Return the mixture control to "normal" position when the engine is throttled down.

Owing to the fact that the engine does not receive its normal cooling air stream until in flight, a maximum duration of ten seconds at full throttle must be rigidly observed.

(7) After setting, the diaphragm and rod should be wire-locked and sealed.

MAGNETOS.

Several types of magnetos are available for fitment. The Watford S.P. 9/4 and S.P. 9/6 and the B.T.H. S.C. 9-5B, S.C. 9-7B and S.C. 9-8. The principle of all is fundamentally the same, in as much as they are of the polar inductor type. All are fitted with automatic advance and retard couplings which cover a range of approximately 15°. The couplings are entirely automatic and are in the full retard position up to 900 R.P.M., and full advance above 1,200 R.P.M.

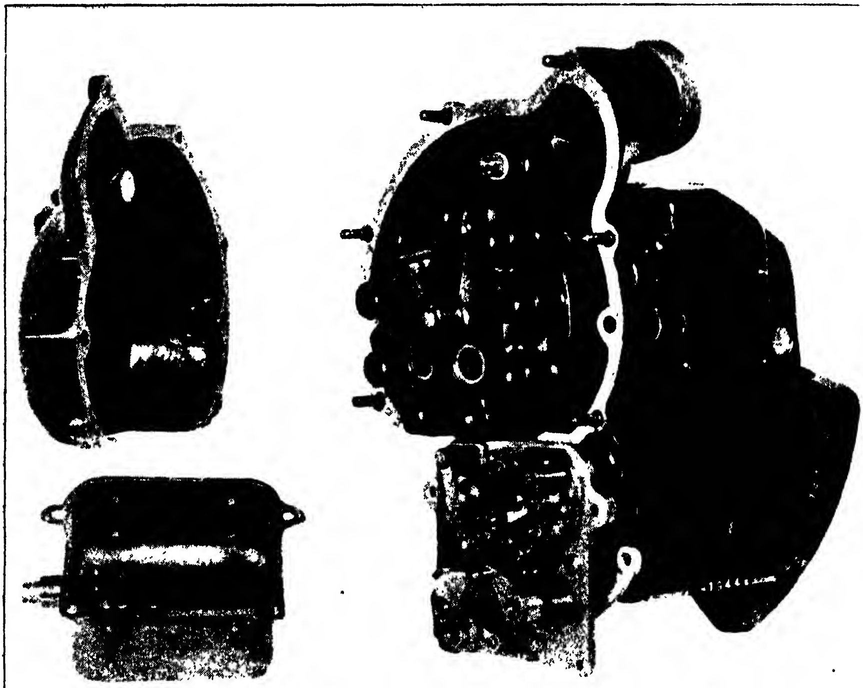


Fig. 37.—Rotax-Watford Dual Contact Breaker Magneto.

Later magnetos are fitted with dual contact breaker units which provide two distinct timings, namely, normal or retarded for " take-off," high power and slow-running, and advance for cruising. Two contact breaker arms, operated from a four lobe cam, are employed; these arms being electrically connected through a switch device operated by a lever outside the magneto. By means of link mechanism, this lever is interconnected with the carburettor throttle busbar so that fully advanced ignition is only available during limited throttle openings.

Operation.—Fig. 38 shows the lay-out of the breaker unit. Two contact breakers: X the fixed or retarded, and Y the adjustable or advanced, are connected in parallel by the switch Z, which is operated

by the cam O. The retarded breaker X is permanently fixed to a base plate, whilst the advanced breaker Y is mounted on an adjustable plate, on the edge of which is a scale R marked off in degrees; this plate can be rotated concentrically and is held by the four set screws D, F, G and E. The advanced contact breaker bell crank is connected to the low tension pick-up and is always in operation. As the high tension spark is produced when the primary current is interrupted, it will be observed that, when the switch Z is closed, the primary current flows to both

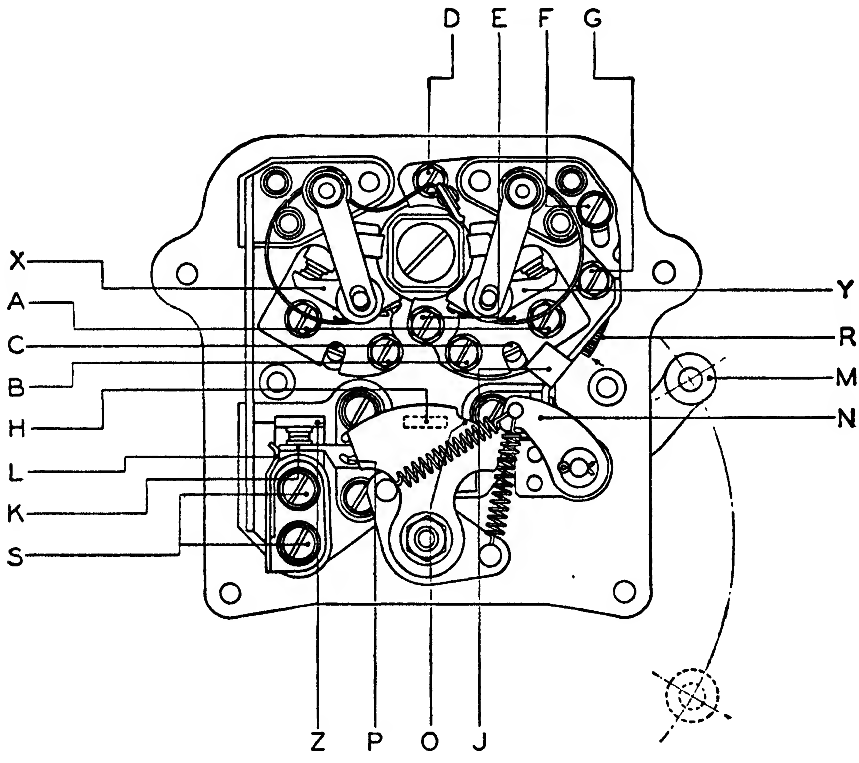


Fig. 38.—Contact Breaker Unit.

breakers and although Y breaks first, no spark is produced until X opens, thus interrupting the current. With the switch Z in the OFF position, the primary circuit is connected to the advanced breaker only, thus giving advanced ignition.

Adjustments.—To adjust the contact breaker points after cleaning, slack off the two screws A and B and turn the eccentric marked C until the correct gap (0·012 in.) is obtained, after which retighten screws A and B.

In order to take advantage of the double contact breaker magneto, the switch must operate quickly. This is achieved by lightly loading the switch contact arm K by a jumper spring L. When the lever M is

moved and the cam follower N falls into the dwell on the cam O, the spring fork P flexes slightly. When the tension on P reaches a value sufficient to overcome the resistance of L, the switch contacts open quickly. Slots are provided in the foot of spring L and adjustment can be made after slackening the screws S.

Ensure that the primary spring H connection to the breaker switch base is clean; also that the earthing platform J is clean and free from oil.

For detailed maintenance of the various types, the makers' handbooks should be consulted.

INSTALLATION.

The installation of an engine in a prototype aircraft is a subject in itself and consequently beyond the scope of this book. The installation of all production aircraft has been thoroughly tested and the various fittings, accessories, controls, etc., approved before the aircraft is passed for service; consequently the following notes are for the guidance of those concerned with an approved installation.

Unpacking.—The engine, as delivered, is packed in a wood case; two types are used, those for engines supplied to civil operators and a special case for Air Ministry engines.

To unpack the engine, first remove the bolts at the top and lift off the lid; then take off the nuts securing each side. This allows the sides to be lifted and drawn away, thus leaving the engine exposed on the stand. The bolts holding the airscrew shaft clamp should now be removed, when the engine is ready for attachment of the sling.

Air Ministry Type Case.—Take out the four bolts, two each side at the bottom of the case, attach a suitable sling to the four lifting links at the top of the case and lift clear of the engine. There is no need to remove the top panel. Remove the front clamp.

Slinging the Engine.—An engine sling, having a suitable spreader, is now required to sling the engine. The sling should be attached to the eye bolt on the rear of the crankcase, and around the airscrew shaft, using plenty of padding to prevent damage to the splines. The weight should now be taken and the bolts retaining the steel mounting plate to the wood uprights removed. The engine may now be hoisted and drawn clear of the stand. Care must be taken to see that the sling does not damage the rocker gear.

Removing Mounting Plate.—Disconnect the automatic throttle control rod, then the override control rod and variable datum control rod. The automatic throttle control rod must not be disconnected from the toggle link levers, but the ends of the latter detached from the toggle link levers on the carburettor. Next remove the upper end of the link rod by turning the rod round until the cross pin is aligned with the transverse hole in the piston rod guide; the pin may then be pushed out and the rod removed. Disconnect the carburettor by taking off the twelve nuts and washers. On Pegasus II-L engines the heater elbow should also be detached. Take off the nuts, when the engine plate may be removed, care being taken not to damage the high tension wires or magnetos.

Installing the Engine in an Aircraft.—Assuming that the engine is to be installed with the fixed cone mounting, standard A.G.S. bolts of the correct length for the air frame mounting should be used; in no circumstances should the bolts used to retain the engine to the packing case plate be used.

In the event of a flexible mounting being used, it should be fitted in the following manner. Sling the engine from the eye bolt on the cone mounting and the airscrew shaft; assemble temporarily five support brackets and four trunnions to the lower half of the cone. Lower the engine carefully on to a special stand (see Fig. 39) until the four trunnions are in line with the four holes in the plate. Slide the arms through the holes and secure

with nuts. Release the sling until the airscrew shaft rests firmly on the front support.

Remove sling and eye bolt from the cone mounting and temporarily fit the remaining four support brackets and five trunnions. Tighten and split pin the top trunnion bolt and temporarily tighten the cap support bracket, also the four bolts securing the two top brackets to the cone mounting; fit the lifting link. Using the new lifting link, sling the engine clear of the stand and tighten and split pin the trunnion bolts. When completed, securely tighten the lower cap support brackets commencing

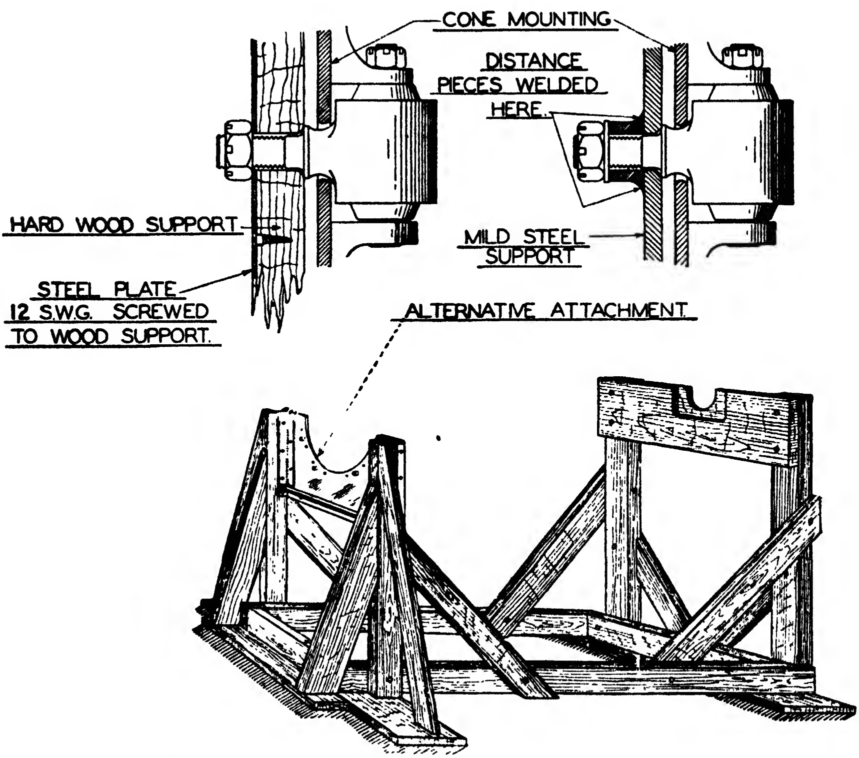


Fig. 39.—Special Stand for Fitting Flexible Mounting.

from the bottom and working upward and ensuring that all the space is taken up between the brackets; finally lock with split pins. In order to tighten the upper cap nuts, lower the engine back on the stand and remove the sling; slacken off the securing bolts of the two upper brackets and lifting link nuts before tightening and pinning the upper cap nuts. Finally tighten and split pin the eighteen nuts and bolts securing the brackets to the cone mounting, working downward; sling the engine whilst securing the lower bolts.

Remove all blanking plates and covers, also the magneto distributors.

Lift the engine to the correct height and guide it carefully into the

mounting, twisting the engine so that one magneto enters at a time. Care must be taken not to damage the distributor rotors, which are exposed owing to the removal of the covers.

Assemble the mounting bolts, pads and nuts—carefully tighten and lock with split pins. (Engines fitted with the flexible rubber mounting, have only nine supporting bolts and nuts).

Refit the magneto distributors and fit the starter magneto wire to the centre terminal on the distributors. Attach the magneto earth wires, one to each of the contact breaker covers.

Take off the carburettor blank and apply jointing compound to the flange face. Place the carburettor, complete, in position on the induction elbow; fit washers and nuts and securely tighten the latter. On certain installations the carburettor and air intake can be fitted on the ground, as either the mounting plate, having a detachable lower segment, or a horse shoe type of mounting plate, is provided, whilst others have a detachable mounting plate which can be fitted to the engine on the ground. On Pegasus II-L the heater elbow and pipe must also be fitted.

Fitting Starters.—Before fitting the E. 160 hand and electric turning gear, or inertia starter, the clearance between the starter jaw and the jaw on the end of the crankshaft tail shaft must be checked. This clearance should be 3/32 in. and to obtain this figure a special laminated shim may be obtained. A check must also be made to ensure that full engagement is obtained between the two jaws, in addition to checking the clearance.

Fitting Oil Pipes.—All rubber joints must be fitted with approved clips and have brass gauze covering. Where bonding strips are used, care must be taken that metal to metal contact is maintained. Carefully wash the bore of the pipes and examine the pipe unions and nipples to ensure the conical faces are clean and free from burrs.

The oil pipes may now be connected in the following order :—

(1) The pipe from the lower connection on the rear of the oil sump to lower forward connection on the scavenge pump casing.

(2) The pipe from the port side of the carburettor body to the upper connection on the scavenge pump casing.

(3) The oil return pipes from the starboard side of the carburettor heater jacket to the oil tank. One pipe will go to the oil cleaner, with a further pipe to a cooler, and a third pipe from cooler to tank.

(4) The oil drain pipe from the union on the rear cover, just below the oil pump, to the upper connection (early engines), or the centre connection (later engines) on the oil sump.

(5) The main oil feed pipe, with thermometer housing incorporated, from the tank to the large union on the starboard side of the rear cover oil filter.

(6) The high initial oil pressure by-pass pipe from the lower rear connection on the scavenge pump casing to the top of the oil tank. (On engines with external by-pass only).

(7) The high initial oil pressure feed pipe from the banjo connection on the scavenge pump casing to the union on the top of the crankcase between cylinders Nos. 1 and 2. It is not usually advisable to disconnect this pipe when removing engine from the air frame.

NOTE.—6 and 7 are only required if the high initial oil pressure device is fitted.

(8) The vent pipe from the connection on the starboard side of the rear cover to the top of the oil tank.

(9) The generator drive drain pipe from the bottom of the engine end of the generator drive casing to a connection formed by a T piece between the end of the oil tank vent pipe and the union on the rear cover. This pipe is not required if the generator drive is above the horizontal centre line.

(10) If a variable pitch airscrew is fitted, connect the pipe from the union on the port side of the gun gear housing on the rear cover, to the rear of No. 1 crankcase bolt, and from the front of this bolt to the union on the oil transfer housing on the front of the reduction gear casing. See that the support bracket is in position.

(11) The supply pipe from the connection on the rear cover behind the gun gear housing to the Romec vacuum pump, if fitted.

(12) Should an R.A.E. air compressor, Rotoplunge pump, or B.T.H. type A.V. air compressor be fitted, the appropriate feed and/or supply pipes should be connected and securely locked.

Do not connect the oil pressure indicator connection on the rear cover until immediately prior to running the engine, as this connection is used for priming the engine.

The main feed pipe and its connections are probably the most critical in the whole oil system; consequently great care must be taken when fitting, since any leak, however small, may result in air being drawn into the pump, resulting in a partial or complete failure of the oil system, which would quickly result in extensive internal damage to the engine.

The scavenge side of the system is also very critical, as air leaks may cause serious consequences owing to the fact that the scavenge pump will be unable to draw from the sump, with the result that the oil will build up and cause excessive over-oiling, which may ultimately result in the engine cutting out. Immediately the pipes are connected, all unions should be tightened and securely locked; most union nuts are provided with drilled holes for wire locking.

Connecting Carburettor Controls.—When assembling the carburettor controls, great care must be taken to ensure that they are connected and checked in the following manner. The arrangement of the components referred to will be seen on reference to Figs. 40 and 41.

Connect the automatic throttle control rod A, override control rod B, variable datum control rod G, and, on later engines, the magneto advance control rod from lever H.

Before connecting the controls in the aircraft to the carburettor, carefully check the movement at the point of attachment to the carburettor, to ensure that the requisite length of travel is available, before the connection is made, in order to obtain the full open or closed positions.

Angular adjustment is provided on the throttle lever C, mixture control lever D and magneto advance operating lever H about their centres. The throttle lever C is adjustable at the lever boss on the face serrations, whilst its outer face serrations engage with those on the magneto advance operating lever, both being secured by means of a ¼ in. nut and split pin.

It is imperative when adjusting the throttle lever C to ensure that the position of the magneto advance operating lever H, relative to the toggle link, is *not* altered.

Four holes are provided on the carburettor throttle control lever. Advantage should be taken of them when connecting up the cockpit control levers to ensure that the full range of throttle movement is obtained.

The mixture control lever D is adjustable on its serrated shaft and is clamped in position by a 2 B.A. nut and bolt, nipping the split boss.

Slight loss of movement, backlash, or spring in the aircraft mixture control system is inevitable at approximately the gate or normal mixture strength position, and a small amount of dead movement or travel in the carburettor mechanism has been provided to accommodate this. It will be found that if the carburettor mixture control lever be moved gently from the weak position to the normal position (indicated by a heavy line on the carburettor dial F), and then moved slightly toward the rich position, the operator will feel the control pick up a little additional load; this is the engagement of the mechanism with the enriching device.

This pick-up takes place approximately one division on the dial on the rich side of the normal position. It is between these two points (the heavy line on the quadrant and the pick-up point) that there is no change in mixture strength in the carburettor setting. This movement has been provided to accommodate errors of backlash in the aircraft controls. It is essential, therefore, that the aircraft controls be adjusted so that any unavoidable backlash that exists, occurs between these two points.

Having made this adjustment, it should be checked to prove the setting in the following manner :—

From the cockpit, the mixture control should be slowly moved from the weak position to the gate or normal position, when the pointer E on the carburettor dial F should come within the two points referred to above ; then move the cockpit control gently from the rich position to the normal position (gate) ; the pointer on the dial should again come between the points referred to above. Under these conditions, the loss of movement in the controls is expended within the two points previously mentioned.

It should be remembered that the full range of mixture control on these carburettors is sufficient for 30,000 feet altitude. It is probable that the aircraft in which the engine is being installed may have a ceiling very much below this height, and for the purpose of providing finer command of the mixture control, only part of the full range may be utilised, *i.e.*, the full traverse of the control lever in the cockpit will only partially cover the dial range from normal to weak.

Provision is made in the aircraft control system for returning the mixture control to the normal position when the throttle is closed. The pick-up of the mixture control by the throttle mechanism should occur at a point when the lever C is approximately 53° from the SHUT position, and corresponding with the correct pick-up mark on the carburettor indicator plate. When checking this position, the boost control piston rod must be held at the top of its stroke. Finally connect the control to the lever operating the slow-running cut-off valves.

After completing the carburettor assembly, connect the revolution indicator flexible drive and wire lock.

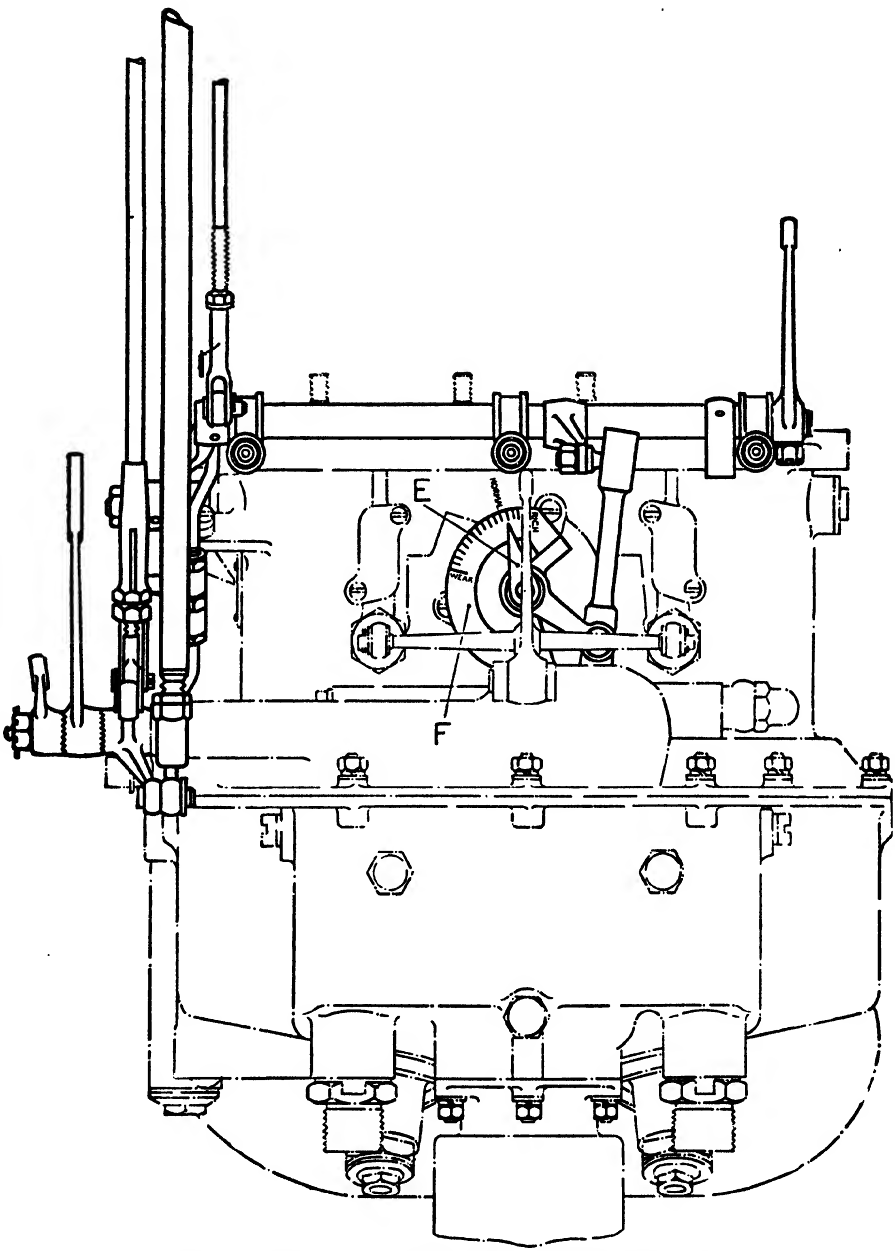


Fig. 40.—Diagram showing Method of Setting Carburettor.

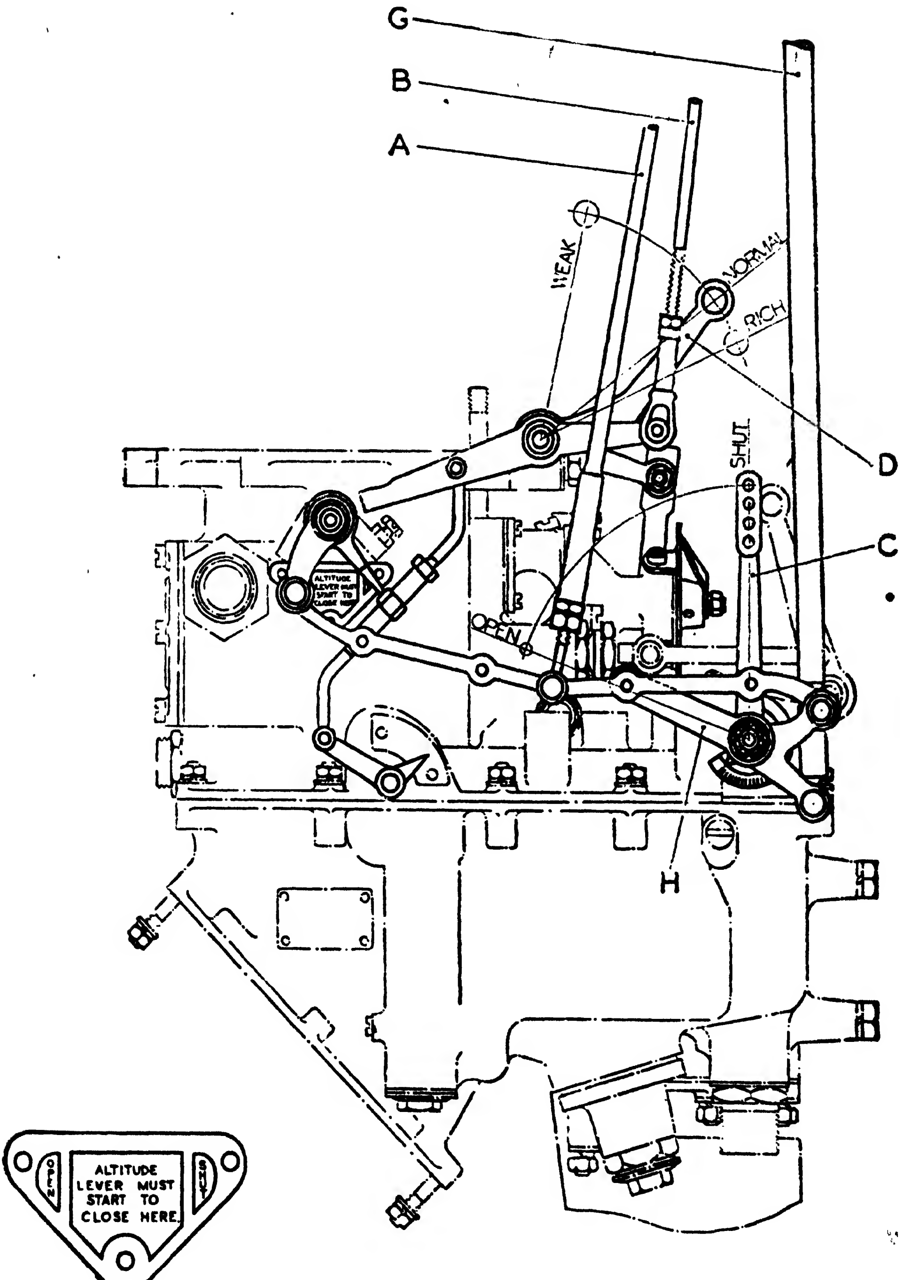


Fig. 41.—Diagram showing Method of Setting Carburettor.

Fit the priming pipe to the priming connection on the rear of the volute casing.

Connect the boost gauge pipe to one of the unions on the volute casing.

If the fuel pump is fitted, connect the fuel pipe from carburettor to the union on the fuel pump marked OUT, and also from the union marked IN to the filter, or other predetermined point in the fuel system. When the dual fuel pump is fitted, connect up the two pressure gauges.

Assemble the air intake to the carburettor and secure with washers and nuts; connect the control for operating the shutters; afterwards check to ensure that their position agrees with the wording on the plate in the cockpit. The various conditions under which the shutter control should work, are as follows. It is important that these instructions be adhered to.

Warm Air (Shutters open).

" Warming up."
Low air temperature.
Gliding.
Damp atmosphere.
Rain.
Clouds.
Snow.

Cold Air (Shutters closed).

" Starting."
Full power.
Fine weather conditions.

Fitting Wood Airscrew and Hub.—Fit airscrew on hub, check the fit on bore and see that the boss faces are true with the hub flanges. Assemble the bolts and front flange, tighten bolts progressively all round until there is no gap between the flange and boss. The final locking and the split pinning of the hub bolts should be left until after a preliminary run, as further tightening will probably then be possible.

Particular care should be paid to the balance of the airscrew, as this is one of the most frequent causes of rough running in service. The airscrew should also be checked for track of blades.

Before fitting the hub, make sure that all anti-rust compound, used for storage purposes, is completely removed from the serrations of both the airscrew shaft and the hub.

Fit the copper protector sleeve over the threads of the airscrew shaft to protect them from damage when sliding on the airscrew hub.

Lightly coat the airscrew shaft splines with approved compound; see that the master spline engages with the corresponding splineway on the hub.

Thread the split collet on to the shaft, and screw home the hexagon headed bronze nut on the end of the shaft. This nut forces the hub up on the splines and should be pulled up as tightly as possible with the special spanner provided; finally tighten it with a 4-lb. hide hammer or equivalent, until movement of the nut ceases. Fit the hub nut locking plate, entering its two tabs in suitable serrations; finally fit circlip.

To remove the airscrew hub from the shaft, liberally coat the threads of the extractor nut with graphite grease and screw into the end of the hub; this nut should only be screwed in finger tight. With the spanner, unscrew the airscrew hub nut; this action will draw the hub off the splines.

On early Pegasus engines a locking nut is provided in addition to hub bolts. Place the locking washer in position and screw on the large serrated nut; then tighten with the special spanner provided. Finally

bend up the tab of the washer into one of the serrations in order to lock the nut. Certain of the early engines and a few of the later type, are provided with a slightly different method of locking the hub nut. Instead of a circlip, a locking plate is provided. Fit the plate, with its tabs in suitable serrations, in the end of the airscrew hub and secure by passing a 2 B.A. bolt through the tongues on the locking plate and the hexagon of the airscrew hub nut; fit nut and split pin.

Fitting the De Havilland Hamilton V.P. Airscrew. When fitting, the following instructions should be strictly adhered to. The airscrew is received complete and, in all respects, ready for flight:

Clean the bore of the airscrew hub, also the splines and the bore of the airscrew shaft, and sparingly coat both with a mixture of graphite and grease.

Take off the cylinder head locking ring A (Fig. 42), and unscrew cylinder head B using box spanner provided and remove gasket C.

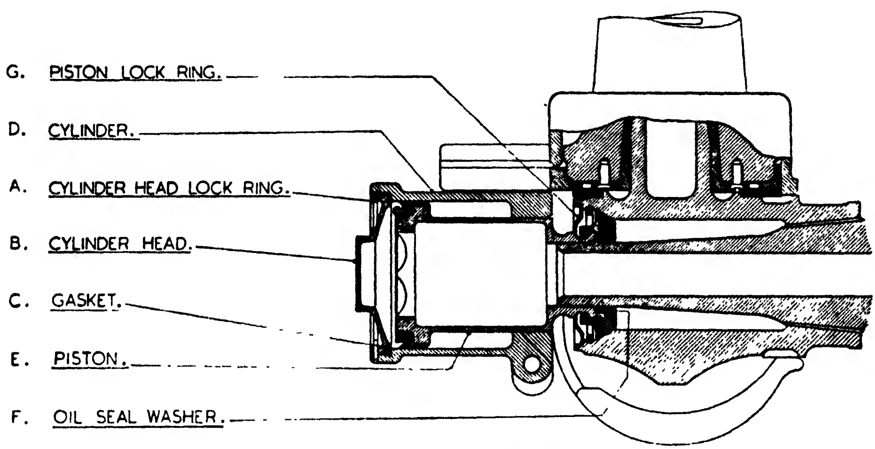


Fig. 42.—Diagram showing method of fitting Variable Pitch Airscrew.

Mount the airscrew on the airscrew shaft, care being taken that the master spline in the hub mates with the corresponding spline on the airscrew shaft. Screw the piston E on to the airscrew shaft using spanner provided. Care must be taken at this stage to ensure that the piston and airscrew shaft threads are properly engaged; in the event of binding or other indication that these threads are not properly started, the piston should be released and a second attempt made. In no circumstances should force be used during the preliminary tightening as serious damage will result. Using the same spanner, finally tighten the piston. (The applied tightening moment should be in the region of eight hundred foot-pounds, *i.e.*, it is satisfactory to apply a force at the end of a three foot bar of from 250 to 300 lbs.). To ensure that the hub is pulled home, the bar should be given a smart blow on the section closest to the hub, with a hammer of not more than 2½ lbs., and with a normal swing; the weight meanwhile being suspended on the end of the bar. Repeat this operation after the first test flight.

No attempt should be made to tighten the piston by hammering on the end of the bar.

Whilst tightening the piston, see that the oil seal washer F does not bind and that it pulls correctly into place. After satisfactory tightening of the piston, secure it with the lock ring G using two or three 3/32 in. split pins, as required, to prevent movement. Fit the cylinder head gasket C care being taken that it rests squarely on the cylinder head; the gasket should be held in position with a thin coating of approved grease.

Replace the cylinder head B and tighten with the spanner provided, finally securing with the locking ring A.

Should there be any vibration of the airscrew while the engine is being run up, it may be due to the presence of air pockets within the blades, as a result of uneven distribution of grease. After initial greasing by pressure grease gun, the engine should be run for two or three minutes, after which the airscrew should be regreased and the engine run again—the operation being repeated until no more grease can be inserted.

Removing V. P. Airscrew from Airscrew Shaft.—Method of removing the airscrew hub is the reverse to installation. The following procedure should be observed :—

(1) Take off the cylinder head lock ring and remove cylinder head, using wrench provided.

(2) Remove piston lock ring by taking out the split pins.

(3) Unscrew piston using the same wrench and special tommy bar as was used for removing cylinder head. This will pull the hub off the engine shaft.

Exhaust System.—As previously explained, spherical joints are provided on the exhaust ring branch pipes, consequently sufficient freedom should be maintained in these joints to enable them to be readily moved by hand. The sleeves at the exhaust ring end must be watched for wear and should be replaced if wear becomes excessive. Exhaust tail pipes must be perfectly in line and freely mounted so that no constraint whatsoever is exerted on the exhaust ring outlet pipe or pipes. The ring and brackets should be periodically examined for any slight cracks which might develop. If any occur, they should be welded up immediately. The taper bolts in the three mounting tripods should maintain a first-class fit in their sockets.

On the small diameter exhaust ring, the tab washers on the nuts securing the bracket to the ring must be turned up in position. As with the large exhaust ring, periodic examination for cracks should be carried out.

PROCEDURE AFTER INSTALLATION OR A LONG STAND BY.

Carefully examine all mounting and engine main external nuts; make sure they are quite tight and safely locked.

Examine the engine controls.

Check over valve clearances on all valves. (See page 142.)

When the wood airscrew is fitted, see that airscrew boss is tight on its hub and the hub tight on the shaft. In the case of the V.P. airscrew, make certain that the hub is tight on the shaft.

Take out all sparking plugs and ascertain they are the correct type; then clean and set the gap (0·012 in. to 0·015 in.). Rotate engine by hand and watch for signs of oil flooding in lower cylinders. If signs are noticeable, make sure that all oil is drained out from cylinders, the induction system and the exhaust system before replacing the spark plugs, as failure to so do may lead to subsequent damage to the engine.

When replacing spark plugs, smear the threads lightly with a mixture of graphite and grease, and fit new washers of the rolled copper type.

Examine the fuel system thoroughly, drain out the tanks, clean the filters, and after replacing, fill up with approved fuel.

Carefully examine the oil system, remove and clean the filters, drain and clean tanks, after which fill up with approved oil, allowing a minimum of 2 gallons, plus 2 gallons for each hour's fuel carried. Suitable filters should be used to relieve the filters in the installation of excessive duty.

Charge the rockers and rocker adjusting screws with grease gun provided, until grease just oozes from the bearing joints. Wipe away surplus; use approved grease.

Inspect the magneto contact breaker, or breakers in the case of the dual contact breaker magneto; check rocker arms for freedom and points for condition and gap.

Remove the magneto distributors, and ensure that starter magneto brush is making good contact with the rotor.

Lubricate the blower gear and bearings by injecting oil through the two nipples on the crankcase and rear cover respectively, by means of the oil gun provided. One gunful of warm engine oil should be injected through the nipple on the rear cover, and four through the one on the crankcase, rotating crankshaft 3 or 4 revolutions immediately afterwards to distribute the oil.

It is most important to ensure that the pump or other device used for priming the engine, also the oil gun for priming the blower bearings, is washed with clean petrol before use. Only clean filtered engine oil should be used for priming the engine and blower bearings, as this oil will subsequently come into circulation; furthermore, it will be necessary to ensure that the normal air space is in the tank after the engine has been run up on the ground.

The instructions for lubricating the blower do not apply if the engine is in continual use, but this procedure should be adopted if the engine has been standing for more than 5 days.

Prime the lubrication system with hot oil (50°C.) under pressure (using approved brand of engine oil).

Ensure that both the pump and the pipes are quite clean and free from foreign matter before the priming operations are commenced. Not less than half a gallon of hot oil should be forced into the engine through the pressure gauge connection on the engine rear cover and a pressure of from 10 to 80 lbs./sq. in. used to enable the priming operation to be completed within a reasonable time. In no circumstances should the pressure be less than 10 lbs./sq. in., as there is the danger of oil escaping past the crank-pin bearings, etc., and thus failing to reach the front end of the crankshaft.

INSTRUCTIONS FOR STARTING THE ENGINE.

Provision is made for starting the engine by the following methods :—

(1) Turning the airscrew by hand.
(2) Turning the airscrew by means of the Huck's starter attachment.
(3) Use of the " Bristol " gas starter. } See Air Publication
(4) Use of the R.A.E. Mk. II starter. } *Gas Starter Systems.*
(5) The Saintin starter or Viet starter. See Makers' Handbook.
(6) The hand (*a*), or electrically operated (*b*), turning gear.
(7) Hand (*a*), or electrically operated (*b*), inertia starter.

Whilst No. 1 may still be used in an emergency, Nos. 1 to 5 are now only applicable to engines up to Series VIII.

(6*a*) Starting with Hand Turning.

(*a*) Turn on the fuel cocks and the cock in the priming system.

(*b*) Set the mixture control in the normal position, and the throttle lever slightly open.

(*c*) Put V.P. airscrew control, if fitted, in the fine pitch (take-off) position.

(*d*) Set the air intake control to position for admitting cold air.

(*e*) Set the cowling gills, if fitted, in the open position.

(*f*) Place the starter and main engine magneto switches in the ON position.

(*g*) Rotate the engine by means of the turning gear and at the same time inject approximately 6 to 8 pumpfuls of fuel into the induction system by means of the priming pump, afterwards turning off the doper fuel cock. With a hot engine, a maximum of three pumpfuls of fuel should be injected. (The amount of priming quoted is the average for normal climatic conditions and may be varied to suit local climatic conditions).

(*h*) Continue turning the engine and at the same time crank the starter magneto vigorously until the engine fires. (On certain installations the starter magneto may be interconnected with the turning gear, in which case the starter magneto switch should not be put into the ON position until the engine has completed approximately two revolutions.

(*i*) As soon as the engine fires, place the starter magneto switch in the OFF position.

(*j*) Set the air intake control to admit warm air.

(6*b*) Starting with Electric Turning Gear.

(*a*) Prepare the engine as detailed in (6*a*), (*a*) to (*f*) inclusive.

(*b*) Prime the engine as detailed in (*g*) but do not turn the engine.

(*c*) Press the starter motor switch and keep in the ON position whilst turning starter magneto, if not interconnected with starter.

The starter motor should not be run for periods longer than ten seconds in order to avoid overheating. The engine should start after approximately three seconds ; should it fail to start in ten seconds, the reason should be investigated, during which time the starter motor will cool down.

Starting with Inertia Starter. Series XI.

(7*a*) Hand Operated Starter.

(*a*) Carry out the procedure as detailed in (6*a*), (*a*) to (*f*).

(*b*) Make certain the operating rod is in the correct position ensuring that the jaws are disengaged.

(*c*) Inject approximately 6 to 8 pumpfuls of fuel into the induction system by means of the priming pump, afterwards turning off the doper fuel cock.

(*d*) Turn the starter crank slowly at first, without applying any great effort, and as the speed increases, exert a greater force. Continue rotating until it reaches a speed of 75 to 80 R.P.M. The time taken to attain this speed should be approximately 30 to 45 seconds.

(*e*) Immediately the requisite speed of the starting handle has been obtained, turn the starter magneto vigorously if not interconnected, then pull the operating rod to engage the starter jaw with the engine crankshaft jaw and hold in engagement until the engine fires.

NOTE.—It is important that the magneto be turned when the dog is engaged, in order to minimise delay, as the engine is only turned 1½ to 3 revolutions.

(*f*) Immediately the engine fires, put the starter magneto switch in the OFF position, and the air intake control to the warm air position.

(*g*) If the engine fails to start, push on the operating lever to ensure disengagement of the drive and repeat the procedure.

It is useless to attempt to start the engine unless the appropriate speed has been obtained on the cranking handle, as the necessary energy will not be available in the flywheel. With experience the operator will learn from the humming note of the flywheel when he has obtained the necessary speed, before operating the clutch lever. Under normal conditions and with air temperature down to 0° C., 75 R.P.M. of the crank handle will give sufficient energy to the flywheel to start the engine from cold after standing all night. When the engine starts, the starter jaws disengage automatically, but care must be taken to ensure that there is no restriction to free movement of the operating rod when returning to the disengaged position.

(7*b*) Electric Inertia Starter.

(*a*) Carry out the procedure as detailed in (6*a*), (*a*) to (*f*). Prime the engine as detailed in (6*a*), (*g*).

(*b*) Push the switch to start the starter motor and keep in the ON position until the flywheel has attained its correct operating speed, five to six seconds usually being sufficient.

(*c*) Immediately the required speed is obtained, pull the switch control. The action of pulling the switch will open the electrical circuit and at the same time engage the starter jaw with the jaw on the engine crankshaft.

(*d*) At the same time as the clutch is engaged, turn the starter magneto vigorously.

(*e*) Immediately the engine fires, place the starter magneto switch in the OFF position and the air intake control to the warm air position.

(*f*) In the event of the engine failing to start, further attempts should be made before injecting more fuel.

NOTE.—The maximum time for operating the starter motor is ten seconds ; should the engine fail to start, further attempts must not be made in less than thirty seconds, in order to allow the motor to cool down.

RUNNING THE ENGINE.

When the engine has started, run at approximately 800 R.P.M. until the oil pressure has risen to its maximum figure. The oil pressure should rise immediately the engine starts ; should there be an excessive lag, or if the oil pressure fails to rise, the engine must be stopped at once and the trouble investigated. It should be noted that the pressure may rise to 250-300 lbs. per sq. in., in the case of those engines fitted with the high initial oil pressure device, *i.e.*; the pressure gauge pointer will register on its stop, but this will soon drop to the normal figure.

If time permits warming up the engine, the speed should be maintained at approximately 800 R.P.M. During this period, observe that the engine is functioning normally.

In the event of it being necessary to open the throttle, immediately after starting (which is permissible in an emergency on engines fitted with the high initial oil pressure device, provided the temperature is above 5°C.), a careful note must be made of the oil pressure and if this falls below 100 lbs. per sq. in. before the oil inlet temperature has reached 15°C., it must be throttled back until the temperature rises.

During the time the high initial oil pressure device is in operation, the oil pressure will vary with the engine speed, but as soon as the device goes out of action, the pressure will settle at 80 lbs./sq. in. If, when it has settled, the pressure fluctuates or is more than 5 lbs./sq. in. below normal, examine the system joints for leaks and, if found, rectify these. The pressure on early engines will settle at 60 lbs./sq. in.

The oil relief valve is adjusted and sealed by the makers, and must only be adjusted by authorised persons. In the event of alterations to the setting being necessary, it is important that the oil temperature be raised to 70°C. before finally sealing the adjustment.

If the engine is running normally, and the required oil temperature of 15°C. has been obtained, open the throttle fully and observe the boost pressure whilst running with the mixture control in the normal position. The maximum take-off boost will be obtained when the overriding device is in action.

Should the boost pressure be incorrect for the specific type of engine, a careful check must be made (*a*) of the attachment of the carburettor to the volute casing ; (*b*) that the aircraft controls are correctly adjusted ; and (*c*) that the boost gauge is reading correctly.

The automatic throttle control and its operating link rods are adjusted on the test bed and afterwards sealed ; no further adjustment should be necessary, but if any be carried out, the fact that the seals have been broken, and the reason for breaking them, must be recorded in the log book.

Do not run at rated boost for longer than 10 to 20 seconds when checking the engine R.P.M. and switches, on the ground, as the engine does not receive its normal cooling airstream until it is in flight. The drop in R.P.M. at rated boost with either magneto switched off, should not be more than 5 per cent of the normal R.P.M. on either magneto. In no circumstances switch off both systems when the engine is running above 800 R.P.M. Check for acceleration and slow-running. Controllable cowling gills, if fitted, are to be open fully whilst ground testing is proceeding.

The mixture control may only be operated on the ground for periods of a few seconds duration for the purpose of testing it, except, of course, when the overriding device is brought into action for take-off.

Checking V.P. Airscrew Control.—To check the functioning of this control, the engine should be throttled back to approximately 1,500 R.P.M. in fine pitch, and the V.P. control changed to coarse pitch (cruising) setting. This should cause the R.P.M. to decrease somewhat, if the pitch operating mechanism is working correctly. Return to fine pitch before shutting down.

After the preliminary run, stop the engine and examine for oil or fuel leaks. Check the V.P. airscrew or airscrew hub for tightness on shaft; finally lock hub nut. Look over all external nuts and retighten if necessary.

Remove and examine the oil filter in the sump for signs of foreign matter; if trace of this be found, drain system and wash out the tanks; repeat running and cleaning operations until the system is clear. In the event of bronze, white metal or other metallic particles being found in the filter, the origin should be located before further running is carried out.

TAKING OFF, CLIMBING AND IN FLIGHT.

Taking off.—When the engine is started (see pages 127 to 129) and the machine ready to take off, place the airscrew blades in the fine pitch position for take-off and the cowling gills fully open, if fitted ; the pilot must then spring the mixture control lever, in the cockpit, through the gate to the rich mixture position to bring the overriding device and, on later engines, the enriching device, into action. The throttle control in the cockpit must then be moved to the full open position, when maximum boost will be obtained. When the mixture control is in the rich mixture position, the automatic boost control is set to permit a given boost according to the series of engine. (See pages 64 and 65).

Climbing.—With the medium supercharged engine, the controls may be left in the take-off position until the aircraft reaches 1,000 ft., when the mixture control should be moved from the override to normal position. If, however, after take-off the aircraft is to be cruised at low altitudes (*i.e.* 1,000 ft. or less), the mixture control must be returned to the normal position within two minutes of taking off. In the case of the fully supercharged engines, the controls may be left in the override position until the aircraft reaches its rated altitude (see pages 64 and 65), when the control should be moved to the normal position.

Climbing with the mixture control lever in the full rich position, after these respective heights have been attained, will only result in a further drop in R.P.M. with a considerable increase in fuel consumption, as the mixture will be excessively rich with the enriching device in operation.

NOTE.—In no circumstances must the maximum permissible climbing revolutions be exceeded (see pages 64 and 65).

In Flight.—In flight, the controls are operated in the normal manner. The automatic boost control regulates the maximum throttle opening, ensuring the rated boost is not exceeded and thus relieving the pilot of the necessity for watching the boost gauge.

(i) **Oil Pressure.**—Stop the flight if the oil pressure falls below dangerous minimum specified. See Leading Particulars (pages 64 and 65).

(ii) **Oil Temperature.**—In flight the inlet oil temperature should not exceed 70°C. for cruising, but for short periods, during a climb, a maximum inlet temperature of 80°C. is permissible.

(iii) **Crankcase Temperatures.**

Take-off and climb - - -	max. 235°C.
All out level - - - -	max. 235°C.
Cruising - - - - -	max. 190°C.
Economy cruising - - -	max. 180°C.

(iv) **R.P.M.**—In level flight, maximum cruising R.P.M. must not be exceeded for longer than five minute periods.

(v) **Vibration.**—No undue vibration should be experienced throughout the speed range of the engine.

Cruising at Economy Setting.—For cruising at the most economical fuel consumption, the mixture control should be operated to reduce the mixture strength until a drop in speed of 3 per cent. of the R.P.M. occurs; maintaining the mixture in this position, open the throttle until the original R.P.M. are regained.

Stopping the Engine.—As explained in the carburettor section of the General Description, cut-out valves are fitted to all later series of carburettor which are controlled from the cockpit. When shutting down, it is therefore necessary to throttle back, then switch off and pull out the cut-out valves. It is important to follow this sequence of operations to prevent the possibility of the engine picking up again on open throttle in the event of the pilot accidentally releasing the valve.

NOTE.—Before stopping the engine, the pilot should move the airscrew blades to the fine pitch position, as this will enable the ground engineer to carry out adjustments and routine inspection more easily.

Use of Cowling Gills (if fitted).—The following may be taken as a general guide for the setting of the cowl gills.

Ground running, Taxying - -	Open.
Take-off and climb - - - -	Open.
Cruising - - - - - - -	Closed.

Experience with the aircraft concerned, in conjunction with cylinder temperature recording apparatus, will enable the pilot to obtain finer control when climbing, but no definite rule can be laid down as to the exact degree of gill opening, as it depends entirely on the speed and power developed.

PROCEDURE FOR STRIPPING.

When dismantling the engine, the following sequence of operations must be strictly adhered to, as any incorrect procedure may result in damage to the various components. It is assumed in the following that the air

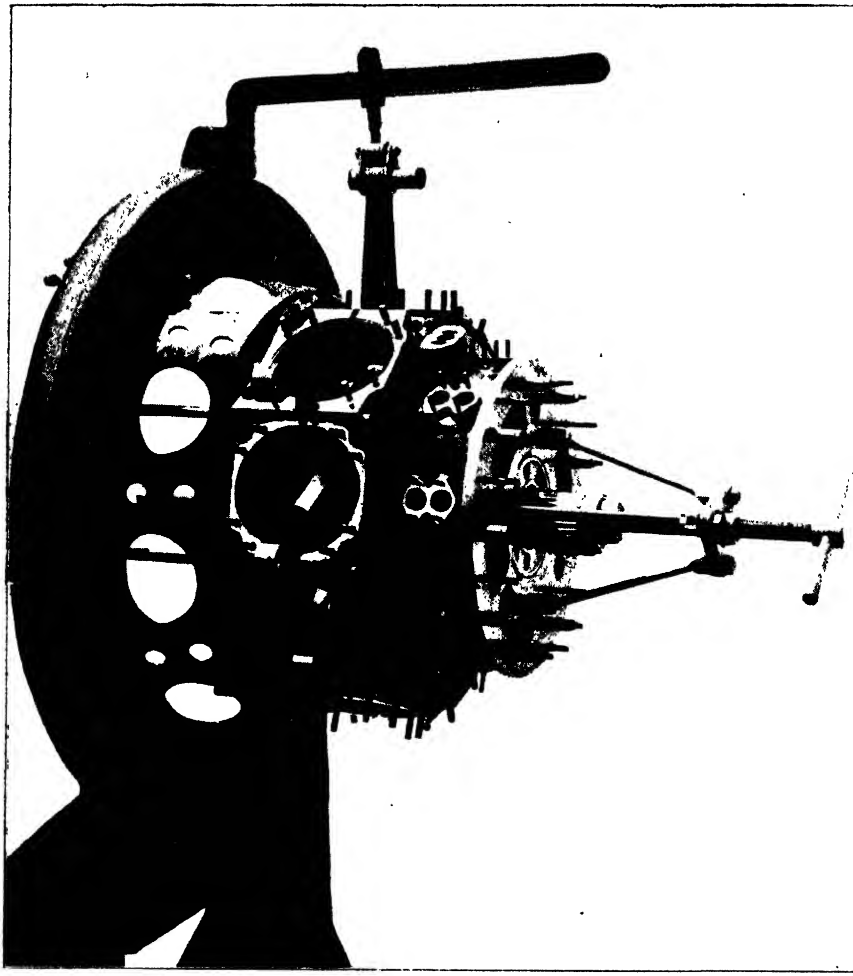


Fig. 43.—Extracting Front Half of Crankcase, showing Connecting Rod Jib.

intake, carburettor, oil pipes and exhaust ring, etc., have been removed when the engine was taken out of the air frame.

(1) Withdraw the distributors from the magnetos and fit protective covers.

(2) Mount the engine on the stand and retain in position by suitable bolts and nuts.

(3) Dismantle the H.T. wires from the distributors.

(4) Dismantle the high initial oil pressure feed pipe and V.P. airscrew feed pipe. Disconnect the two boost control pressure balance pipes.

(5) Take off the starter as a unit.

(6) Remove two screws and withdraw tachometer drive complete.

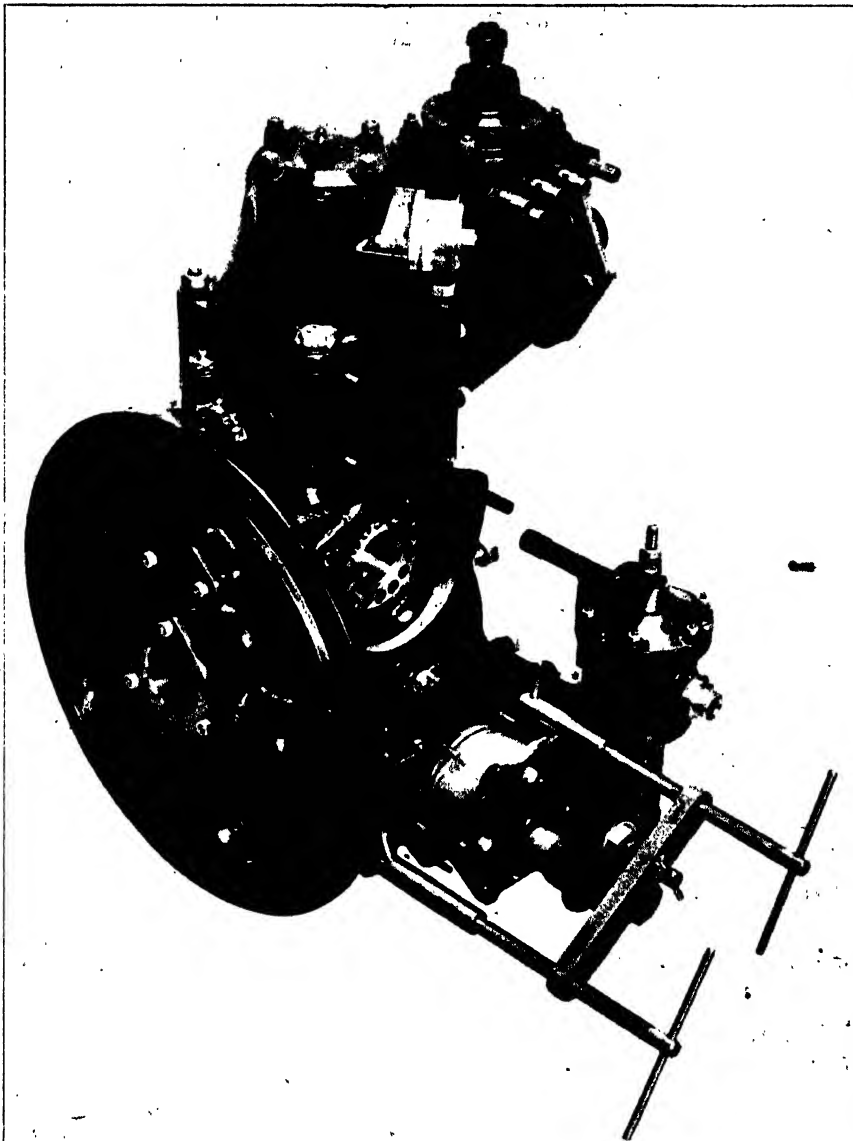


Fig. 44.—Extracting Oil Pump from Rear Cover.

(7) Remove B.T.H. air compressor and fuel pump complete from the compressor drive casing.

(8) Withdraw the cross drive housing.

(9) Dismantle the cross drive shaft.

(10) Withdraw the starter jaw using extractor.

(11) Detach the rear cover from the volute casing, taking care to avoid damage to the tail shaft bearing.

(12) Remove the reduction gear unit complete.

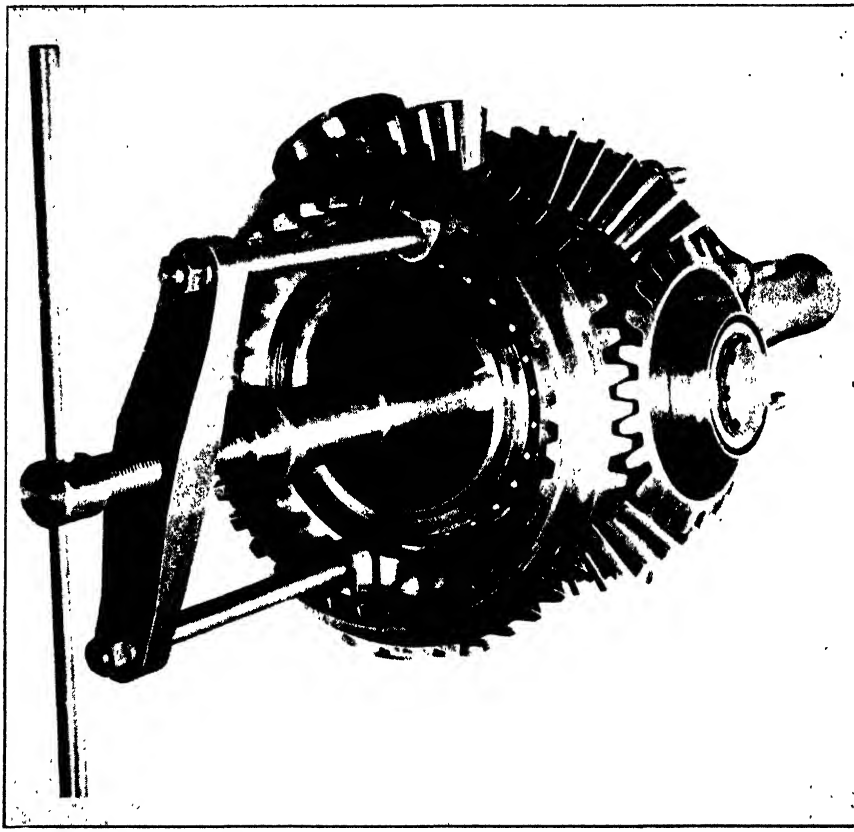


Fig. 45.—Extracting Rear Bevel Gear.

(13) Remove the rocker covers and slacken back the rocker adjusting screws. Unscrew the rocker bracket bolt nuts and withdraw the bolts. Swing the rocker brackets up and simultaneously withdraw the push rod heads. Remove the push rod units complete, followed by the packing plates. Note that the crankshaft should be rotated so that the valves are closed before withdrawing the bolts.

(14) Unscrew the left hand threaded driving gear nut and withdraw the driving gear from the crankshaft. Remove the crankshaft bearing thrust nut and withdraw the front cover complete with ball bearing.

(15) Remove the tappet guides complete with tappets and rollers.

(16) Slide the serrated cam drive gear off the crankshaft and extract the cam and crankshaft sleeves. Finally remove the key.

(17) Remove the oil sump.

(18) Take off joint ring holder at the base of each induction pipe and raise both ring and holder clear of studs.

(19) Remove the cylinder holding down nuts. The cylinders may now be removed by pulling them radially outward. Each piston should be steadied as soon as exposed in order to avoid damage which may occur by the skirt falling against the connecting rod. Remove the pistons. Guard plates should be fitted to locate the connecting rod in position.

INSPECTION.

It is impossible in the space available to give full details of inspection procedure, but to those responsible, the Bristol Aeroplane Co. Ltd. will be pleased to supply particulars. It is most important that every engine be thoroughly inspected in accordance with standard procedure when it is stripped after having completed its allotted running time.

ENGINE ERECTION.

(1) Assemble the cone mounting to the engine erection stand. When the flexible rubber engine mounting is used and the special type of stand is available, the mounting should be assembled to the cone mounting as follows :—

Assemble each flexible mounting block and support bracket round the cone. Ensure that the two brackets, which form the anchorage for the lifting link, are positioned on either side of the vertical centre line of No. 1 cylinder. For correct assembly, the solid end of the inner sleeve of the rubber mounting should be fitted toward the cap support bracket. Loosely assemble the eighteen bolts and nuts and secure the support brackets to the cone mounting. Securely tighten and split pin the trunnion bolts. Equally space the support brackets; tighten and lock the nuts securing the cap support brackets. Next tighten and lock the eighteen bolts and nuts securing the support brackets to the cone mounting; fit the lifting link.

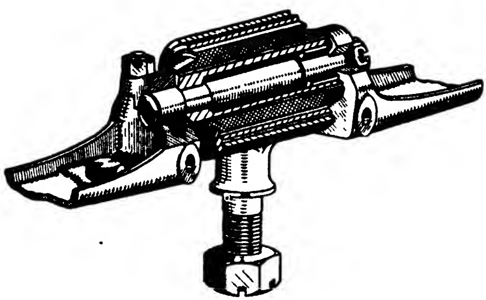


Fig. 46.—Flexible Mounting Unit.

Fit the cone mounting to the erection stand.

(2) Fit tab washers to the crankcase bolts. Fit the rear half crankcase to the cone mounting, with No. 1 aperture aligned with the lifting link, and assemble the crankcase bolts.

(3) Suspend the crankshaft assembly, by the master rod gudgeon pin bore, from the jib; assemble the bearing rollers on the crankshaft inner races and retain in position with a rubber band. (Fig. 47.)

(4) Align the master rod with No. 6 aperture and position the articulated rods in line with their respective apertures. Guide the crankshaft assembly into position. (The rubber band used to retain the rollers will be displaced and should be removed).

(5) Assemble the front half crankcase in correct position, *i.e.*, No. 1 aperture at top, and after applying jointing compound to the joint faces, ensure that front and rear sump joint faces are in line. Fit a tab washer and nut to each bolt; securely tighten and lock. Remove the jib and front rubber ring; fit the protector plates.

(6) Commence by fitting No. 6 piston and cylinder, for the purpose of steadying the connecting rod assembly. Space the gas and scraper ring gaps evenly and ensure that they are correctly assembled. Place the piston

over the gudgeon pin " eye " with the cylinder numeral, engraved on the gudgeon pin boss, toward the front of the engine. Insert the gudgeon pin and position it centrally between the piston bosses. Assemble the

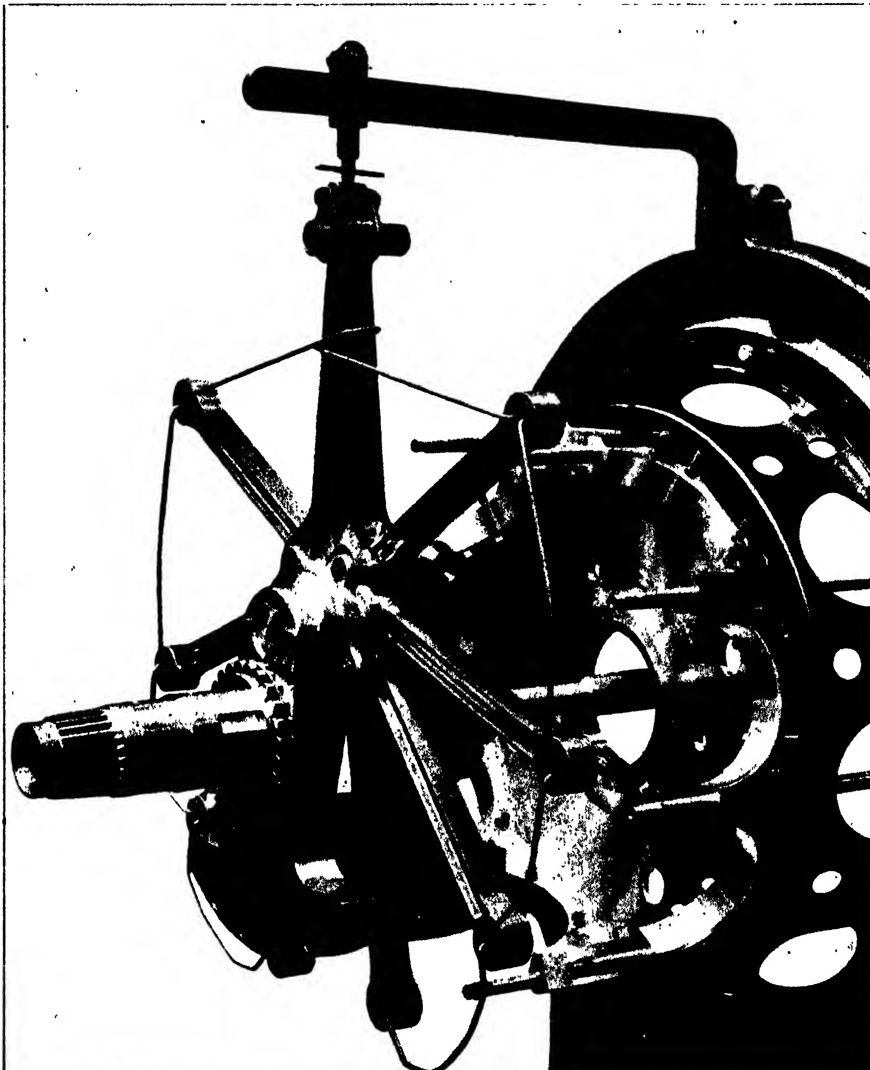


Fig. 47.—Assembling Crankshaft and Connecting Rods to Rear Half of Crankcase. (Note rubber bands retaining rollers.)

ring on one end and fit the circlip, using tools provided. Repeat the operation at the opposite end of the pin. Check circlips for security and ensure that gudgeon pin is free to rotate.

(7) Fit new rubber packing ring to the cylinder barrel spigot and apply engine oil. Compress the piston rings, using tool provided, and assemble the cylinder. Fit the tab washers and nuts; securely tighten and lock.

(8) Assemble the remaining pistons and cylinders in the sequence Nos. 3, 1, 8, 4, 2, 7 and 5. No. 9 must not be fitted at this stage, since the aperture is utilised for inspecting the centralisation of the connecting rod assembly.

(9) Assemble the oil sump in position, using new washers.

(10) Fit the crankshaft key (figure " O " toward the front). Insert the crankshaft sleeve in the bore of the cam sleeve with the flanged and

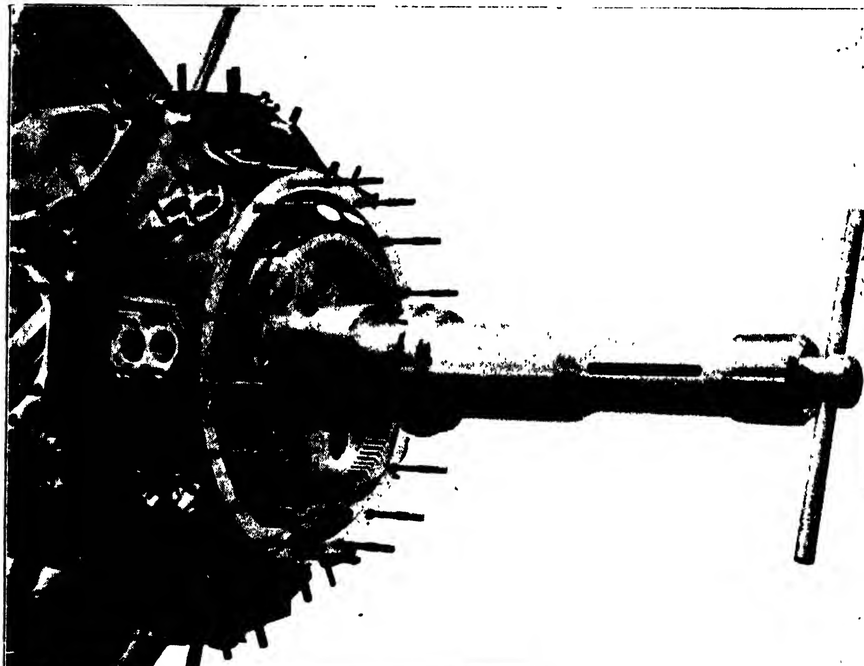


Fig. 48.—Pressing on Cam Sleeve, with Special Tool.

serrated end toward the front. Fit protecting sleeve and assemble the crankshaft sleeve, with cam sleeve, on to the crankshaft; align the keyway with the key and press into position, using special tools. (Fig. 48.)

(11) Align one of the small holes in the cam sleeve with the hole in the wall of the front half crankcase. Rotate crankshaft until the blind hole in the front balance weight is aligned with the two stated above. Apply jointing compound to the front cover rear joint face and assemble to the crankcase. Fit nuts and suitable distance pieces.

Replacement of the cam, layshaft gear and layshaft, will necessitate checking the backlash of these components. Insert special tool into the bore of the layshaft. Attach a dial indicator to the front cover. The tool arm is engraved with two separate markings representing the pitch line on the layshaft pinion and layshaft gear. Adjust indicator on to the

pinion line and check the backlash with the crankshaft in various positions. Assemble the cam drive gear on the crankshaft and check the backlash in the same manner, after setting the indicator on the appropriate marking in the tool arm.

(12) Insert timing bar through the layshaft bore and through the holes mentioned above. Centralise the crankshaft movement resulting from the clearance of the timing bar in the holes. Observe the amount of accumulative backlash for layshaft pinion and cam sleeve and position the gear midway. Note the position of the layshaft teeth in relation to the serrations on the crankshaft sleeve and select on the cam drive gear a position to correspond. Insert the gear into position, noting that backlash is not taken up in either direction.

(13) Fit the centralising shims (if any) and press the front journal bearing into position, using special tools. Fit the retaining ring, tab washer and crankshaft lock nut ; use special spanner to tighten.

(14) Inspect the centralisation of the gudgeon pin eyes between the internal faces of the bosses of their piston ; the eyes should be central. If satisfactory, lock crankshaft nut.

(15) Assemble No. 9 piston and cylinder as previously described.

(16) Fit the rubber ring to each tappet guide ; apply oil and assemble each guide and tappet complete to its appropriate bore.

(17) Fit the tappet guide packing pieces in position. Assemble the push rod unit complete over the studs ; fit the tab washers and nuts. Slacken back the rocker adjusting screws and swing the rocker unit downward. Whilst the rocker is being lowered over the tie rod eye, both inlet and exhaust push rod heads should be guided into the push rod upper ends.

(18) Align bolt bore in tie rod and rocker bracket and insert the bolt. Fit tab washer and nut.

(19) Check the angle of attack of both inlet and exhaust rockers as follows :—Ensure that the push rod heads are seating firmly on their hardened steel bases. Turn crankshaft until the piston of the cylinder on which the check is to be made is on T.D.C. firing stroke. Unscrew rocker adjusting screws to their full extent. Place the special gauge on the rocker bracket, with the blade projecting downward between the two inlet rockers. The clearance between the push rod head and the blade of the gauge is determined by the use of feeler gauges, the measurement obtained by these gauges giving the setting of the push rod head in relation to the datum line, which is a line joining the centres of the two rocker shaft assemblies.

If, with the gauge in position, no feeler gauges can be inserted, the low limit of 0·150 in. is indicated between the push rod head and the rocker button. Where feeler gauges can be inserted between the gauge blade and the push rod head, the resulting clearance is a direct measure of the number of thousandths of an inch that the push rod head lies below the datum line ; the maximum permissible limit is 0·170 in.

Where the " low " limit is exceeded, the push rod lower ends are to be removed, and the push rod tube length reduced to the desired amount. If the " high " limit is exceeded, it will be necessary to replace the existing push rods with longer ones. The length of the tie rod should not be altered. On conclusion of this check, lock the bracket bolt nut and tie rod bracket stud nuts.

(20) All felt pads are to be soaked in oil, Specification D.T.D. 109

(Mineral), at a temperature of 50°C. for a minimum period of one hour. (The inlet pad need not be removed from the rocker cover). Fit the exhaust felt pads to their respective cylinders. When fitting new inlet and/or exhaust felt pads, careful check must be made to ensure that the total lift of each pad is 0·100 in.

Assemble the felt pads in the valve upper washer, followed by the retainer and circlip.

On later engines, fit the split felt block in position on the push rod cover flange.

(21) Rotate crankshaft until No. 1 piston is on T.D.C., firing stroke. Set the rocker adjusting screw clearances to 0·004 in. for the inlet and 0·006 in. for the exhaust. The clearances must be set on the highest of the four dwells between the lobes on the cam sleeve. To obtain this, first set the clearances on No. 1 cylinder, rotate the crankshaft two revolutions, which will bring next cam dwell into position, and recheck on No. 1. Repeat for all four dwells. The highest dwell will give the lowest clearance reading and clearances on all cylinders must then be set on this dwell. Care must be taken that both inlet valves are adjusted to the same clearance and similarly that both exhaust valves are likewise adjusted. Two sets of feeler gauges should be used simultaneously. Adjust the valves on the remaining cylinders.

(22) The valve timing is checked on No. 6 cylinder. Fit the piston indicator in the spark plug hole and place the timing disc on the crankshaft. Fit the pointer. Determine T.D.C. firing stroke for No. 6 piston by the indicator and set pointer to 0° T.D.C. line on timing disc. Recheck by rotating crankshaft 10° before and after T.D.C. line, noting that the piston indicator readings are identical. Check the valve timing in the following sequence: exhaust opening, inlet opening, exhaust closing, inlet closing; and the results should conform to the timing diagram given on pages 64 and 65.

(23) Fit the two spring keys to the rear half crankshaft with figures " 1 " and " 0 " toward the front. Assemble the spring drive gear as per markings, employing soft alloy drift. Fit the tab washer and nut; securely tighten and lock. Place the rubber ring in position on the external diameter of the crankcase spigot and apply engine oil. Assemble the blower unit, noting that the induction elbow is aligned between Nos. 5 and 6 cylinders. (Check that the primer oil pipe is correctly positioned over the channel in blower casing). Fit the tab washers and nuts, after fitting H.T. wire clamp plate to No. 5 bolts. Tighten the nuts and lock.

(24) Fit the rubber packing to the recess in the inlet pipe branches before assembling them to the volute casing. Fit the rubber joint rings and holders to the inlet pipes before inserting each into the induction elbow. Apply approved jointing compound to both sides of the elbow packing and place in position on the inlet port joint faces. Assemble the induction elbows to the cylinders (each is marked for correct assembly); each outside stud is to be fitted with a support clip for carrying the high tension wires, except wires Nos. 3, 4A, 7 and 8A, which have support clips and guards.

Slide the inlet pipes into the pipe branches and tighten and lock the set screw in each elbow. Position the upper and lower rubber rings against the flange faces and secure the ring holders with nuts and washers. (*NOTE.*—An even clearance all round should exist between flanged holder faces and

the flanged faces of the elbow and branch pipes). As the priming system brackets are fitted to certain studs at a later stage, these nuts and washers can be assembled later.

(25) Assemble priming system (3 or 7 cylinder type) in position. Secure the brackets and clips to the studs on the branch pipes and elbows.

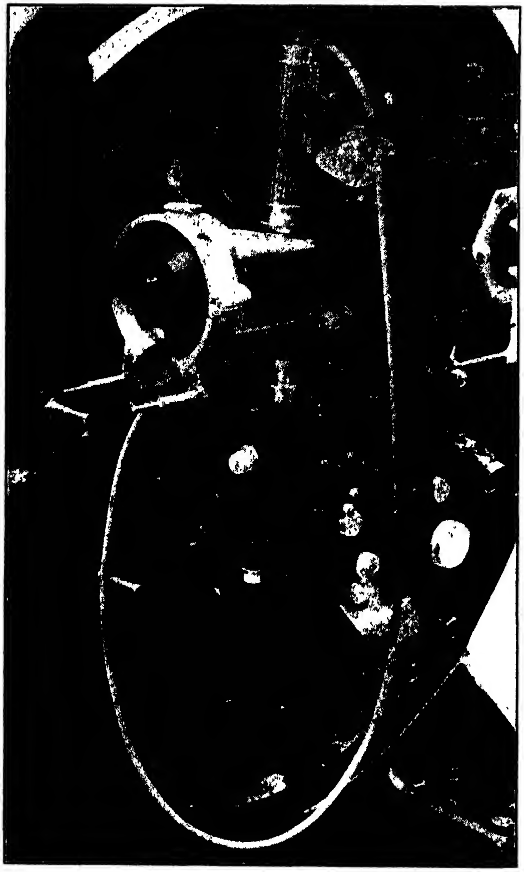


Fig. 49.—Checking Magneto Timing by means of a Hand Torch.

(26) As previously stated, the tachometer drive and cross drive shaft should not be fitted to the rear cover at this stage. Place the rubber ring over the spigot on the rear cover joint face; apply engine oil and assemble the rear cover to the volute casing. Fit tab washers and nuts; tighten the latter and lock.

(27) Assemble the starter jaw on the end of the crankshaft tail shaft. Assemble the cross drive shaft and housing, and tachometer drive and housing, to the rear cover; followed by the compressor drive casing, if fitted.

(28) Assuming that the H.T. wires have not been dismantled from the cone mounting, the lower supports should be attached to the branch pipes

and the upper sleeves clipped into position. Assemble the sectioned wire clamps; progressively place the wires in their correct position and tighten the nuts. Check each wire for continuity and insulation, using a hand torch and hand starter magneto, respectively. On later engines with Marconi harness, proceed as follows:—Align the harness with No. 1 cylinder and thread the cables through the respective orifices in the cone mounting. Locate the harness in position by securing the retaining clips to the crank-case bolts. Assemble the H.T. wire supports to the induction branch pipes. Check for insulation and continuity.

(29) The ignition timing for both magnetos is set on No. 6 cylinder. Using a timing disc and indicator, determine the pointer setting for T.D.C. firing stroke. Rotate the crankshaft anti-clockwise (facing front of engine) through about 40° and then rotate it in a clock-wise direction until the pointer indicates the correct timing as given on pages 64 and 65. Maintain in this position whilst subsequent operations are carried out.

Replace the key in the magneto driving shaft; assemble the automatic coupling and fit the tab washer and nut.

Remove the contact breaker cover and insulate the low tension circuit. Lock the automatic coupling in fully advanced position. Set the distributor brush slightly before No. 6 segment and the breaker points about to separate. Assemble the outer serrated driving plate in such a position that the dogs will mesh with the slots in the magneto driving drum; temporarily fit the nuts. Assemble the magneto to the rear cover and wire the torch as illustrated in Fig. 49. Check the timing on all four cam lobes and the variation should not exceed 2°. Similarly time the second magneto, and check both for synchronisation.

On completion, remove magnetos, lock driving plate nuts, remove insulating silk and release the automatic coupling. Apply jointing compound to both sides of the magneto distance pieces and assemble the magnetos.

On later engines with dual contact breaker magneto, the procedure is as follows:—Temporarily insulate the low tension circuit by inserting insulating silk beneath the brass low tension pick-up. Lock the automatic coupling in the fully advanced position. Set the distributor rotor to position slightly before No. 6 segment and the contacts of the left hand or retarded contact breaker at 'just breaking'. Assemble the outer driving plate in such a position that the dogs will mesh with the slots in the magneto driving drum; temporarily fit the nuts. Assemble the magneto to the rear cover and wire the torch as illustrated in Fig. 50. Place the operating switch in the OFF position and check the timing on all four lobes of the cam on the magneto rotor shaft; the variation should not exceed 2°. Having satisfactorily obtained the retarded setting, transfer the torch cable to the right hand, or advanced, rocker arm. Set this contact breaker at the correct figure (see pages 64 and 65) before T.D.C., by adjusting the plate carrying the unit which is held by the four set screws D, E, F, and G (Fig. 38). Repeat the foregoing instructions for the second magneto and finally check both for synchronisation. On completion, remove the magnetos, lock driving plate nuts, remove insulating silk and release the automatic coupling. Apply jointing compound to the magneto distance pieces and assemble the magnetos. Connect up each control tube to the intercontrol lever and magneto control lever. Fit the cross tube and synchronise the two magnetos.

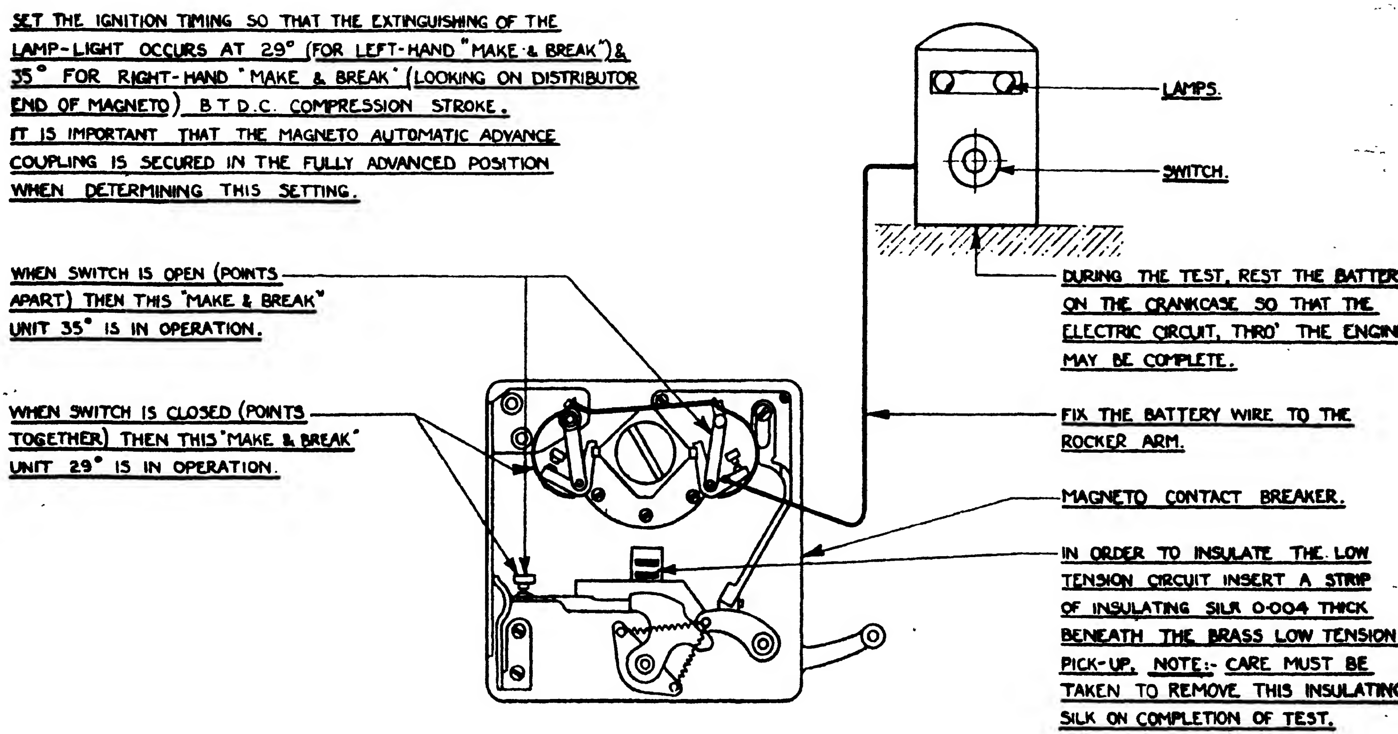


Fig. 50.—Lamp and Battery Test for Ignition Timing. (Watford Magneto, Dual Contact Breaker).

(30) Position engine with No. 1 cylinder vertical. Rotate crankshaft until No. 1 piston is T.D.C. induction stroke and the crankshaft master spline is aligned with No. 1 cylinder. Assemble the reduction gear driving wheel, fit the lock washer and nut ; securely tighten the latter and lock. Remove the distance pieces from the front cover studs. Apply joining compound to the reduction gear case joint face. Align the airscrew shaft master spline with that of the crankshaft ; ensure that the marked tooth on the rear bevel gear will mate between the two marked teeth on the driving wheel. Assemble the reduction gear unit to the crankcase with the master spline, identification and licence plates aligned in the vertical centre line. This ensures correct positioning of the oil drain holes. Assemble the nuts and washers. When a V.P. airscrew is fitted, the oil pipe support bracket should be fitted with tab washers and nuts.

V.P. Oil Pipes.—Fit the rear oil pipe from the banjo connection on No. 1 crankcase bolt to the union on the port side of the gun gear housing. Insert the front supply pipe through the bush in the support bracket and assemble to the union on the oil transfer casing and to the union on No. 1 crankcase bolt.

High Initial Oil Pressure Supply.—Insert the lower supply pipe through the H.T. wire holder behind No. 3 cylinder and connect the lower end of the pipe to the banjo connection on the oil pump body. Fit the upper pipe to the nozzle between cylinders Nos. 1 and 2 and to the upper end of the lower pipe.

Automatic Throttle Control Pipes.—Fit the upper control pipe from the union on the port side of the control casing to the volute casing and assemble the lower pipe between the control valve cover and volute casing.

Starting Unit.—Prior to assembling the starter unit, pour one quart of engine oil into the rear cover through the starter aperture.

TESTING.

The engine must now be tested in accordance with Air Ministry procedure before being passed for strip and rebuild, and final test. Details may be obtained from the Air Ministry Publications Dept.

ROUTINE MAINTENANCE.

As soon as the machine lands, obtain and examine the pilot's report. In the event of there being any remarks regarding abnormal engine running, the necessary examination and adjustments should be made forthwith.

(1) After Each Day's Flight.

(*a*) See that the switches are in the OFF position.
(*b*) Carefully inspect all engine controls and see that locking devices are intact.
(*c*) Check tightness and locking of all main nuts and bolts.
(*d*) Carry out a visual examination of the valve gear; see that all valve springs are intact and the hardened buttons pressed into the end of the valve stems are secure. If excessive wear of stem buttons is found, examine the corresponding adjusting screw thrust button for sticking, as this is the most likely cause of the trouble developing; both should be replaced if wear is apparent.
(*e*) Inspect all fuel pipes and joints.
(*f*) Clean out the fuel filters.
(*g*) Replenish fuel and oil tanks with approved fuel and oil.
(*h*) Examine all H.T. leads and see that the spark plug connections are secure.
(*i*) Test the throttle and mixture controls, also the air intake shutters and slow-running cut-out controls, for freedom of movement.

(2) After Each 10 Hours Running. (In addition to daily adjustments).

(*a*) Check over the exhaust system, pipe joints and fastenings, and ensure that the required amount of freedom is present in the exhaust pipe joints.
(*b*) Remove the filter in oil sump, and examine for metallic particles; clean and replace. The presence of metallic particles in suspension with the oil indicates some abnormal condition and immediate investigation is necessary to trace the source.
(*c*) Lubricate the V.P. airscrew blades (if fitted) through the nipples provided, using Intava Grease A. Clean and lubricate the exposed portion of the piston, using the same grease. This should be done with the blades in the coarse pitch position. Remove the counterweight bearing cap and smear bearings with same grease. Examine the hub for any signs of oil leaks past the leather washer.
(*d*) Check by hand the clearances of all valves, and, if considered excessive, reset in accordance with the instructions given on page 142.
(*e*) Examine and carry out the makers' instructions regarding the maintenance of the B.T.H. type A.V.-A. air compressor. (Also see p. 250).

(3) After Each 20 Hours Running. (In addition to daily and 10 hour adjustments).

(*a*) Examine rocker adjusting screw thrust buttons for excessive wear.
(*b*) Remove rocker bracket covers and inspect the tie rod bolts and rocker fulcrum for signs of slackness. Replace bolts if necessary. Also examine the push rod upper ends.

(*c*) Remove, clean and reset the gaps on all spark plugs ; when replacing, fit new Lodge rolled copper type washers where necessary ; smear the threads lightly with a mixture of graphite and grease.

(*d*) Lubricate the rocker adjusting screws, and, on early engines, the valves guides also, with approved grease.

(*e*) Check the compression on each cylinder. To carry out this check, remove one spark plug from each cylinder, except the cylinder being tested. On completion of this individual test, remove one plug and fit into the next cylinder to be checked, and so on until each cylinder has been tried in turn. In the event of a cylinder being found with weak compression, it should be removed and the cause located.

(*f*) Examine magneto contact breakers, check points for condition and gap, and rocker arms for freedom.

(*g*) Disconnect the fuel pipes at the carburettor and flush out the system. Reconnect pipes and wire lock where necessary.

(4) **After Each 40 Hours Running.** (In addition to daily, 10 and 20 hour adjustments).

(*a*) Drain the oil from the tank, pump system, and sump. This operation should be carried out whilst the oil is hot to ensure complete draining. Flush out the oil tank with flushing oil or paraffin. In the event of paraffin being used, a final flushing should be carried out with clean petrol. Do not, in any circumstances, allow petrol or paraffin to enter the engine lubrication system, and make sure that the tank and oil system are clear of petrol and paraffin before refilling with new oil.

(*b*) Examine oil cleaner for metallic particles and general cleanliness.

(*c*) Drain and clean the oil cooler in a similar manner to that described above for the tanks.

(*d*) Lubricate the magnetos in accordance with the instructions given on the magnetos.

(*e*) Examine and clean magneto distributor.

(*f*) Remove carburettor float chamber base plug and clean ; examine for water deposit.

(*g*) Lubricate the felt pads in the valve spring upper washer, using engine oil D.T.D. 109.

(*h*) Inspect and calibrate boost gauge as per instructions regarding the maintenance of this instrument. It is most important that this instruction be adhered to at the periods stated.

(*j*) Lubricate (single type) fuel pump bearings. Check the union nuts and locking devices, also the relief valve cap for security on both single and dual type pumps.

(*k*) Inspect the V.P. airscrew for tightness on airscrew shaft, using spanner provided. Relock after retightening in the approved manner. If wood airscrew is fitted, remove airscrew and hub. Examine the split taper collet, also the splines in the hub and on the airscrew shaft. Tighten the hub bolts and re-split pin.

(5) **After 120 Hours Running.** (In addition to daily, 10, 20 and 40 hour adjustments).

(*a*) Charge the rockers with approved grease until discharging around the bearings, using grease gun provided. Wipe away surplus lubricant.

(*b*) Remove the rocker bracket cover carrying the felt pad, also remove

the felt pad from the bottom of the rocker bracket and submerge the pads in a bath of engine oil (D.T.D. 109) at 50°C. for a minimum period of one hour. After soaking, remove from bath and drain off all surplus oil. Refit the pad to the bottom of the rocker bracket and replace the rocker bracket cover. Care should be taken to segregate each pad to its respective cylinder, since on initial assembly each is fitted to give a specific lift. When fitting new inlet and/or exhaust felt pads, careful check must be made to ensure that the total lift of each pad is 0·100 in.

NOTE.—In no circumstances should the pads be washed, and only when replacement becomes necessary should the pad be removed from the rocker bracket cover.

(*c*) Remove the felt pads from the valve spring upper washers and soak them in engine oil in a similar manner to that detailed above for the rocker pads.

(*d*) Replace the Tecalemit oil filter element.

(6) Weekly Maintenance.

Every week the engine should be thoroughly inspected, all nuts tightened, locking devices replaced where necessary, particular attention being paid to the following :—

(*a*) Carefully examine all fuel and oil connections, particularly those on the suction side of the fuel and oil pumps.

(*b*) Examine all controls, see that they are properly locked and pins unworn.

(*c*) Lubricate the control rod fork ends and bulkhead slides.

(*d*) Examine engine mounting securing nuts and bolts, particular attention being paid to the flexible mounting units.

(*e*) In the case of engines fitted with 14 mm. spark plugs, both the plug and adapter should be inspected for tightness.

Overhaul Periods.

The length of periods between overhauls is dependent on the operating conditions. The engine manufacturers will be pleased to give operators their recommendations in this connection immediately on receipt of full details of their operating and climatic conditions, such as revolutions per minute, altitude and boost pressure employed for cruising. Particulars should also be given of the fuel and oil used, also the cylinder temperatures reached on climb and under cruising conditions.

SECTION II—IN-LINE

PART 1.—DE HAVILLAND—"GIPSY MAJOR"

By A. J. BRANT,
Service Manager, De Havilland Aircraft Co. Ltd.

INTRODUCTION.

The "Gipsy Major" Aero Engine has been in production for a considerable time and the number in service installed in a variety of types of aircraft now amounts to several thousands.

The "Series II." engine is now in production, and is designed to utilise, if desired, fuel containing tetra-ethyl lead, and to drive airscrews of the controllable pitch type. It thus meets modern requirements in two particular respects, and will be the subject matter of this section. A few notes, however, on the basic differences between the Gipsy Major Series I. and Series II. will not be amiss and prove of interest and value to the student reader.

The Series II. Gipsy Major is not a mere adaptation of the Series I., but has been redesigned wherever change is required to meet its specific function.

The Series I. engine is suitable for fixed-pitch type airscrew only, and a tapered and keyed crankshaft is fitted to accommodate a boss for this type of airscrew.

The Series II. crankshaft is splined at the front end to take a controllable-pitch airscrew, though it is equally suitable for receiving a fixed-pitch metal or wooden airscrew, on special hub.

The crankcase of the Series II. is redesigned to withstand the bigger power output and to provide the oil feed for the operation of the airscrew pitch-changing mechanism.

The rear crankcase cover embodies a new auxiliary drive for a vacuum pump to operate gyroscopic navigation instruments.

The Series I. cylinder heads are constructed of aluminium bronze, and the valves seat directly in the material of the head, and fuels containing tetra-ethyl lead are not permitted. In the case of the Series II. to resist the effects of lead, cylinder heads of aluminium alloy (L. 11) with inserted valve seats of high-expansion steel are necessary and the exhaust valves are Stellited to give an extra hard seating face. Also, to resist lead, a new type of bottom-seating sparking plug is fitted.

The compression ratio of the Series II. engine is 6 to 1, compared with 5·25 to 1 in the Series I., and the maximum power is 140 B.H.P. compared with 130 B.H.P. For operation at the higher compression, fuel of 77 octane rating is required. Air Ministry fuels D.T.D. 224 (without lead) and D.T.D. 230 (leaded) conform to this requirement; moreover, many doped automobile fuels have a 77 octane rating and are obtainable almost univer-

sally. Fuels containing up to 4 cc. of tetra-ethyl lead per gallon may be freely used, but it should be understood that unleaded 77-octane fuels such as D.T.D. 224 are eminently suitable.

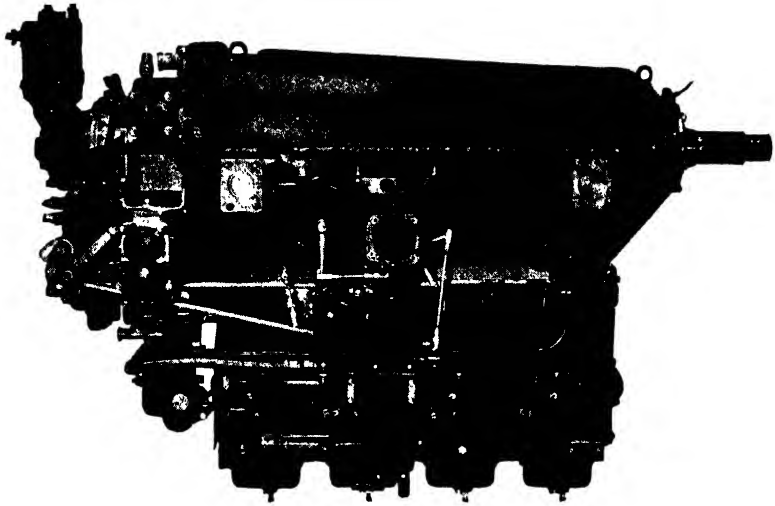


Fig. 1.—Starboard View, Gipsy Major II.

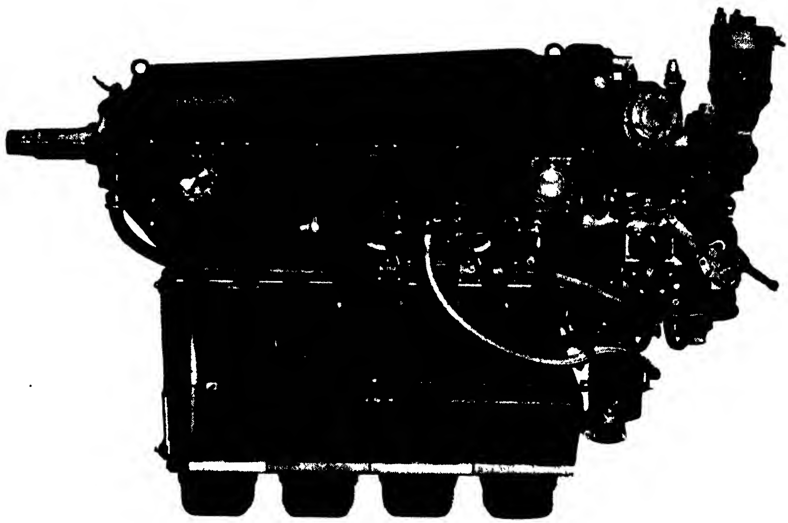


Fig..2.—Port View, Gipsy Major II.

The opportunity of redesigning the cylinder head has been taken to incorporate the base of the rocker box integrally with this unit, also to redesign the rocker box, making it very simple to dismantle. At the same time, a new rocker-box cover of cast magnesium alloy has been produced

having an improved oil-tight joint. To withstand the additional loads of stronger valve springs the rocker arms and their bearings have been completely redesigned. To give a clearer get-away for exhaust gases, change has been made in the form of the exhaust port. A new design of induction manifold has been embodied.

Exhaustive research has been conducted with the cylinder head and valve gear to improve the performance and to permit of the higher outputs. Pistons which are forged in aluminium alloy (L. 42) have been introduced to withstand the effects of the use of weak mixtures for economical cruising at relatively high duties.

The Series I. cylinders are parallel bore and the Series II. taper bore.

LEADING PARTICULARS.

Engine Type Classification - - -	Four cylinder in line, inverted, air-cooled, direct drive, dry sump.
Numbering of Cylinders - - -	Airscrew 1, 2, 3, 4 from front.
Firing Order - - - - - - -	1, 3, 4, 2.
Bore - - - - - - - - -	118 mm. (4·646 in.).
Stroke - - - - - - - -	140 mm. (5·512 in.).
Compression ratio - - - - -	6 to 1.
Direction of Rotation of Airscrew -	Left-Hand Tractor.
Crankshaft R.P.M., International -	2400 R.P.M.

RATED POWER.

At International R.P.M. - - -	132-138 B.H.P.

BOOST PRESSURE.

Maximum for Take-off - - - -	Full Throttle.
Maximum for Climbing Flight - -	Full Throttle.
Maximum for "All Out" Level Flight (5 mins. limit)	Full Throttle.
Maximum recommended for Continuous Cruising - - - - - - -	Minus 3 lbs. per sq. inch.
Maximum Control Setting for Economical Cruising - - - - - -	Weakest Mixture for Maximum Power.

REVOLUTIONS. (R.P.M.)

Maximum for Take Off - - - -	2400
Minimum for Take Off at Full Throttle	1985
Maximum for Climbing Flight - -	2400
Maximum for "All Out" Level Flight (5 mins. limit) - - - - - -	2400
Maximum for Continuous Cruising -	2100
Maximum for Economical Cruising -	2000

IGNITION.

Timing - - - - - - - -	Interconnected with Throttle.
Timing on Full Throttle - - -	30° before Outer Dead Centre.
Contact Breaker Gap - - - -	0·011 in.-0·013 in.
Sparking Plug Gap - - - - -	0·012 in.-0·015 in.

Sparking Plugs.

K.L.G., Type V. 14-1 or Lodge A.14-3.

Valve Timing.

Inlet Valve Tappet Clearance - -	0·005 in. (cold).
Exhaust Valve Tappet Clearance -	0·005 in. (cold).
Inlet Valve Opens - - - - - -	32¾° before Outer Dead Centre.
Inlet Valve Closes - - - - - -	82¾° after Inner Dead Centre.
Exhaust Valve Opens - - - - -	79¼° before Inner Dead Centre.
Exhaust Valve Closes - - - - -	36¼° after Outer Dead Centre.

SPECIAL NOTE.—Owing to misunderstandings having arisen due to the expressions " Top Dead Centre " and " Bottom Dead Centre " on the inverted type of engine, these positions are now referred to as " Inner Dead Centre " (piston farthest from cylinder head) and " Outer Dead Centre " (piston nearest to cylinder head).

Fuel.

Minimum Octane No. 77, D.T.D. 224 (no lead) and D.T.D. 230. (Containing 4 cc. of tetra-ethyl lead per gallon).

Fuel Consumption.

Fuel consumption climbing at 2100 R.P.M. and full throttle near ground level, with mixture in the fully rich position - - - - - - -	9¾-10¼ gallons per hour.
Fuel consumption, cruising at 2100 R.P.M. near ground level (approx. 95 B.H.P.) with mixture control adjusted to give weakest mixture for maximum power - - - - - -	6-6½ gallons per hour.
Fuel consumption for all-out level flight at 2400 R.P.M. and full throttle, near ground level, with mixture control in the fully rich position - - - -	10¼-10¾ gallons per hour.

The above figures refer to engines fitted with a conventional fixed pitch airscrew giving 2400 R.P.M. at full throttle in level flight, near ground level.

Lubrication.

Oil Consumption at normal R.P.M. -	1 to 3 pints per hour.
Normal Oil Pressure in flight - -	40 to 45 lbs. per sq. inch.
Inlet Oil Temperatures—Climbing -	80°C.
Inlet Oil Temperatures—Cruising - -	70°C.
Inlet Oil Temperatures—Emergency Running of not more than 5 mins.	90°C.

Approved Oils.

Oil to specification D.T.D. 109.

In addition a large range of proprietary brands are approved by

the engine manufacturer, and a list is given herewith alphabetically arranged.

S = Summer. W = Winter. A = Arctic conditions.

Grade of Oil.	Supplier.	Use.
Aero Shell Heavy	Shell Mex and B.P. Co. Ltd.	S
Aero Shell Medium	Shell Mex and B.P. Co. Ltd.	W
Intava, Green Band. M	Intava Ltd.	S
Intava, Red Band. M	Intava Ltd.	W
Castrolaero C.	C. C. Wakefield and Co. Ltd.	SW
Double Shell	Shell Mex and B.P. Co. Ltd.	A
D.T.D. 109	-	SW
Germ Motoil XH	Germ Lubricants	SW
Mobiloil A	Vacuum Oil Co. Ltd.	A
Patent Castrol CW	C. C. Wakefield and Co. Ltd.	A
Patent Castrol XXL	C. C. Wakefield and Co. Ltd.	W
Castrolaero XXL	C. C. Wakefield and Co. Ltd.	S

Standard Engine.

The standard engine is equipped as follows :—

Carburettor	Claudel Hobson A.1. 48 (latest type).
Tachometer Drive	Single : Engine Speed.
Flame Trap	Amal.
Ignition	2 unscreened B.T.H. A.G. 4-4 Magnetos. One fitted with an impulse starter. K.L.G. V. 14-1 or Lodge A. 14-3 Sparking Plugs.
Airscrew Boss (Fixed Pitch)	For Wooden Airscrew.

Alternative and Optional Extra Equipment.

Oil system modified to make engine suitable for use with a D.H. two pitch airscrew.
Oil system modified and governor fitted to make engine suitable for use with a D.H. constant speed airscrew.
Airscrew boss for fixed pitch metal airscrew.
Screened B.T.H. magnetos and screened K.L.G. R.V. 14-1 or Lodge R.A. 14/3 Sparking Plugs.
Two D.H.A.C. Petrol Pumps.
Eclipse Hand Turning Gear.
B.T.H. horizontal inertia starter.
Rotax starter—type No. Y. 150 B.
Pulley-operated controls.
Thermo couples fitted to the cylinder heads.
Dual engine speed tachometer.
Vacuum Pump for driving Sperry instruments.
Tappet rod casing sleeves (used on engines operating in sand-laden atmospheres).
Carburettor Flooder.
Single connection for Negretti and Zambra oil pressure gauge.
Double connection for Negretti and Zambra oil pressure gauge.

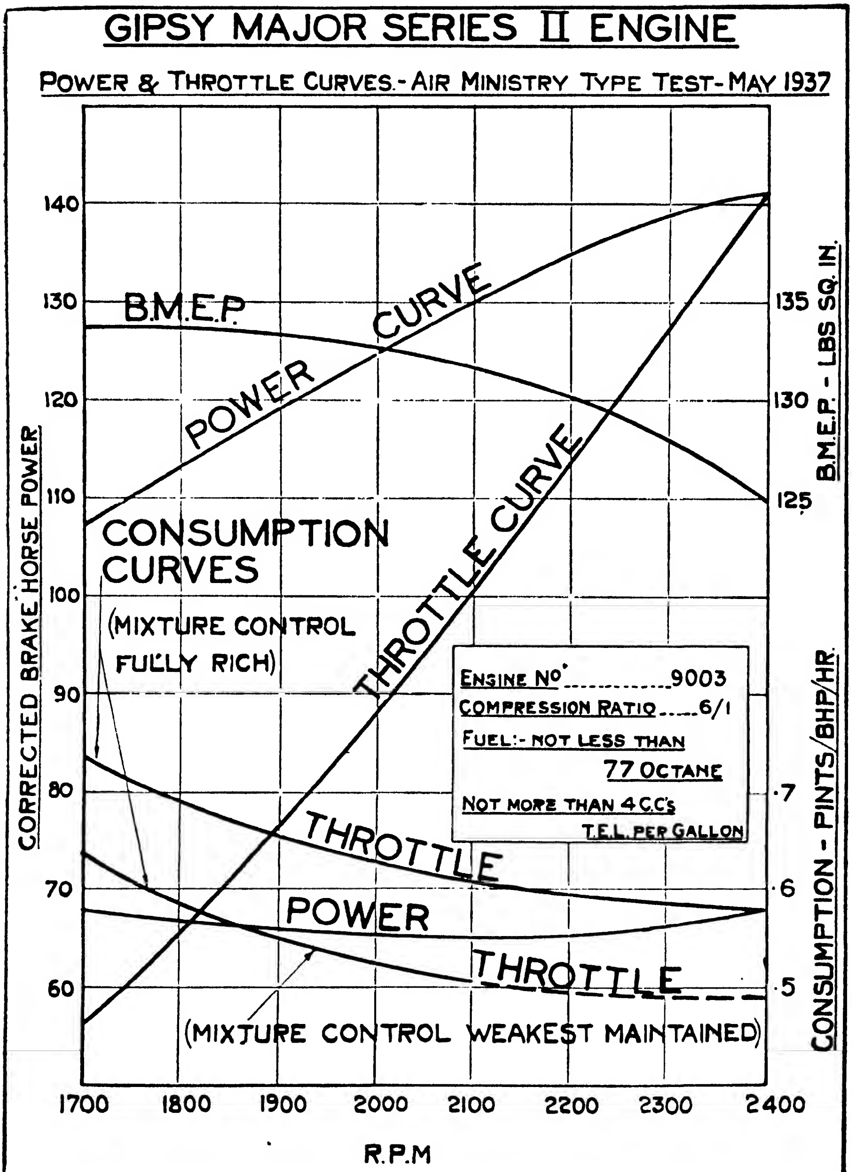
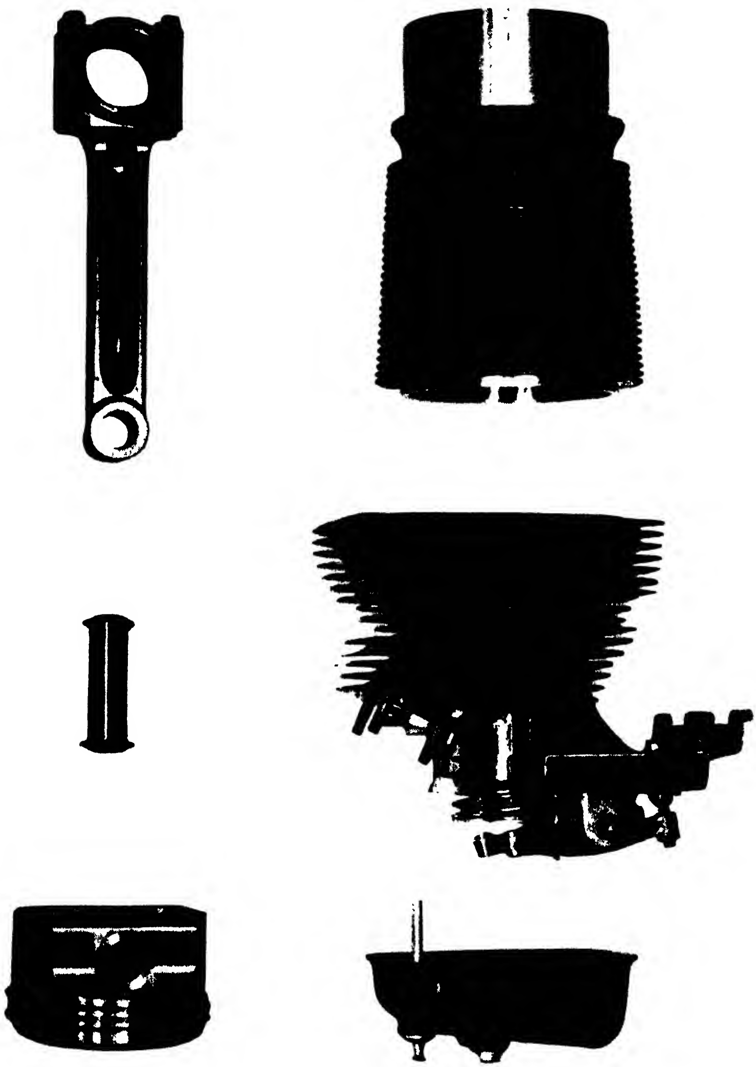

GIPSY MAJOR SERIES II ENGINE
POWER & THROTTLE CURVES.-AIR MINISTRY TYPE TEST-MAY 1937
B.M.E.P.
POWER CURVE
THROTTLE CURVE
CONSUMPTION CURVES
(MIXTURE CONTROL FULLY RICH)
ENGINE NO. 9003
COMPRESSION RATIO 6/1
FUEL:- NOT LESS THAN 77 OCTANE
NOT MORE THAN 4 C.C's T.E.L. PER GALLON
THROTTLE
POWER
THROTTLE
(MIXTURE CONTROL WEAKEST MAINTAINED)
CORRECTED BRAKE HORSE POWER
140
130
120
110
100
90
80
70
60
B.M.E.P. - LBS SQ. IN.
135
130
125
CONSUMPTION - PINTS/BHP/HR.
·7
·6
·5
1700
1800
1900
2000
2100
2200
2300
2400
R.P.M

Fig. 3.

GENERAL CONSTRUCTION.

Cylinder Head.—This is an aluminium alloy casting, which is held to the cylinder barrel by four high tensile steel studs screwed at their upper ends into the crankcase. The joint between the head and the cylinder is made by a copper asbestos washer which fits into a recess in the cylinder



Connecting Rod, Gudgeon Pin and Piston.

Cylinder, Cylinder Head and Valve Gear Cover.

Fig. 4.

head. Flanged bronze guides are fitted for one inlet and one exhaust valve, the high expansion steel seating being shrunk and peened into position in the cylinder head. Dual ignition is provided by two 14 mm. sparking plugs, fitted one in each side of the cylinder head. The cylinder heads are

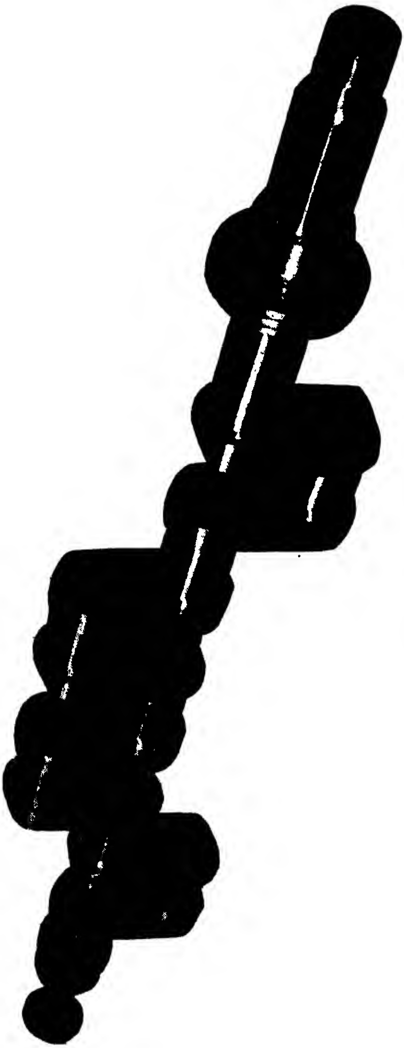


Fig. 5.—Crankshaft with Gear.

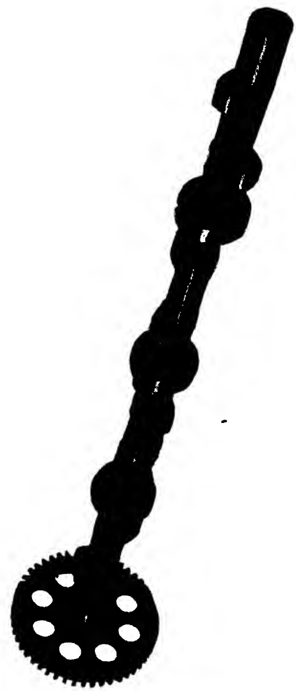


Fig. 6.—Camshaft with Gear.

provided with liberal fin area, and the inlet and exhaust ports are arranged on the right-hand side of the engine.

Cylinder.—This is a carbon steel forging, machined externally to form cooling fins and ground internally, special attention being directed to the graduation of wall thickness and depth of finning in order that distortion

may be avoided and an even cooling effect obtained. An intermediate flange is formed on the barrel together with spigots at either end. One spigot fits into the crankcase to the extent of the flange on the barrel, an oil tight joint being formed by compressing a Dermatine ring between the radius of the flange and the chamfered edge of the crankcase bore.

Piston.—This is machined from a forging of aluminium alloy and is of the slipper type, so designed that the stress from the crown is taken direct to the gudgeon pin, which floats in both the piston and small end of the connecting rod, and is retained by external circlips and washers at each end. Three rings are fitted to each piston, the inner ring being of the scraper type, which deals with surplus oil from the cylinder wall and deflects it through a series of small drilled holes to the inside of the piston and so back to the crankcase.

Connecting Rod.—This is of D.T.D. 130 (high tensile steel) alloy, a forging of H section, the big end is split and houses the steel-backed white metal bearing which is clamped by four high tensile steel bolts. Leak holes are provided in the cap of the rod and bearing, to distribute oil for cylinder, tappet and camshaft lubrication. The small end is plain and unbushed, and drilled to supply oil to the gudgeon pin.

Crankshaft.—This is a nickel-chrome steel forging machined to form a five journal crankshaft. The webs support in one plane the four crankpins, of which the centre two together oppose the outer two. The journals and crankpins are bored and capped, and the webs from No. 2 journal to Nos. 1 and 2 crankpins, and from No. 4 journal to Nos. 3 and 4 crankpins, are drilled to afford pressure feed lubrication to the connecting rod big ends. The front end of the crankshaft is splined for the reception of the airscrew hub, and the rear end is splined internally to take the gear operating the camshaft auxiliaries.

Airscrew Hub (Fixed Pitch).—The airscrew hub is fitted over the splined extension of the crankshaft, and centralised by means of a split steel cone and aluminium bronze cone at front and rear respectively. When a wooden airscrew is fitted it is centralised on the hub by means of a narrow raised land which is situated on the centre line of the airscrew. This narrow centralising land is used to overcome splitting of the airscrew boss, which can occur if a wooden airscrew contracts on to its hub. When a metal fixed pitch airscrew is fitted, a hub can be supplied on which there is no narrow land as described above, the airscrew fitting over and centralising on to the hub in the usual manner.

The front plate is splined to the hub of the airscrew boss, being positively driven, and the eight bolts are relieved of unnecessary stress.

Crankcase and Top Cover.—The crankcase is a deep section casting of magnesium alloy. The front wall and tapered section between them carry the housing for the long front main bearing. The rear bearing housing is carried by the rear wall of the crankcase. Each of the intermediate bearings is held by separate caps, thus facilitating assembly, overhaul and inspection, as none of these bearings need be disturbed when the crankcase top cover is removed. The protrusion of the cylinder barrels converts the lower part of the crankcase into a sump, holes in the cross webs permitting the oil to flow to front or rear of the engine, where drain outlets, provided in the right-hand side wall of the crankcase opposite No. 1 cylinder, and in the base of the rear cover, respectively, enable the surplus oil to be returned

to the tank. A facing is provided at crankshaft centre level to which the crankcase top cover is attached by bolts. This top cover is bored at the front end in conjunction with the crankcase to form a housing for the special type thrust ball bearing, the rear end is faced vertically to take the rear cover while internal transverse webs assist stiffening.

Camshaft.—This is of steel with eight integral cams, and is borne in bearings in the lower part of the crankcase on the port side. The three intermediate journals run in bearings bored directly in the cross webs of the crankcase and are of large diameter to enable the camshaft to be with-

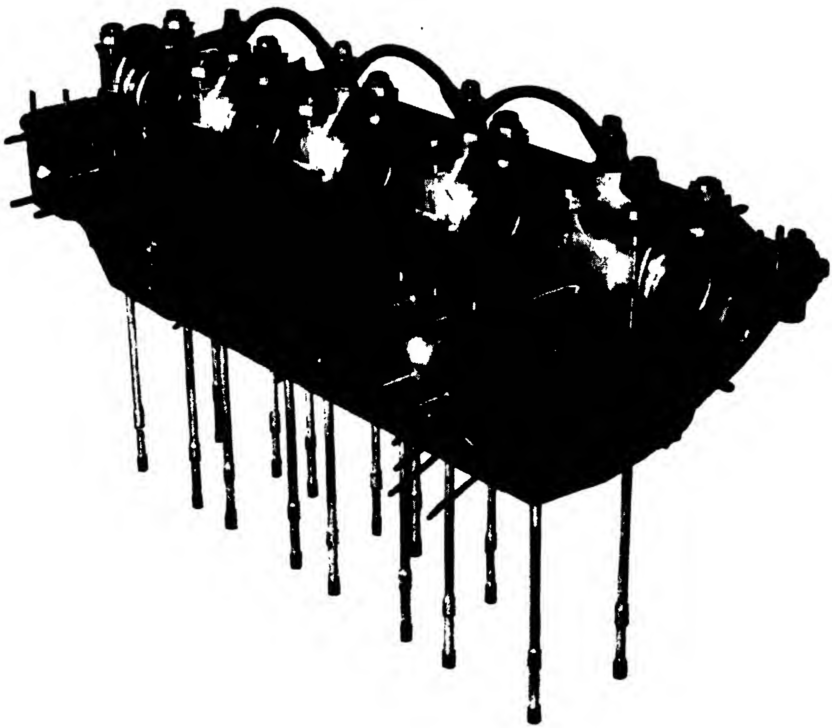


Fig. 7.—Crankcase.

drawn from the rear. The front and rear bearings are aluminium alloy and magnesium alloy respectively and are bolted to the crankcase. The bearings are lubricated by oil mist via holes drilled in crankcase. The spur wheel driving the camshaft is vernier keyed to the extreme rear end and secured by a nut and tab washer.

Valve Operating Gear.—Each cam operates a sliding tappet which lifts the valve by means of the usual tappet rod and rocker mechanism, the closing of the valve and the return stroke of the tappet being accomplished by the action of the dual valve springs. The tappet is square ended at the cam end to prevent rotation and is bored from the other end for the greater part of its length, also through the side at the square end, and fitted with a ball to engage the tappet rod. The tappet reciprocates

in a flanged guide, housed in the crankcase and bolted to the lower face. The tappet rod is of D.T.D. 130, fitted at the upper and lower ends with a cup and ball end respectively. The steel rocker, which has a phosphor

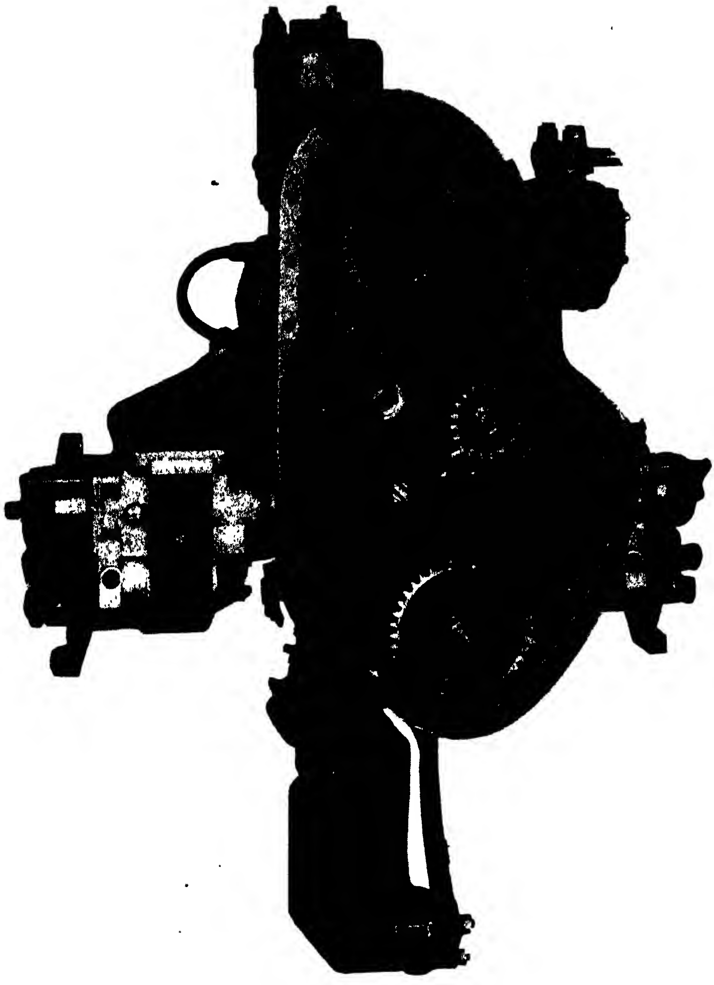


Fig. 8.—Internal View of Rear Cover.

bronze bush, pivots about its offset centre on a hardened steel spindle which is held in a stamped steel bracket.

At the push rod end, the rocker is tapped to receive a hardened steel screwed cup end and locknut, by means of which tappet clearance is adjusted. The other end of the rocker is fitted with a rivetted-in hardened steel pad. A telescopic cover encloses the tappet rod and seats outwardly

under the action of an enclosed central spring, against Dermatine rings in the tappet guide flange at the crankcase, and in a facing on the top side of the cylinder head. The valves, rockers, etc. are completely enclosed by a cast elektron box held in position on the underside of the cylinder head by a cap nut.

Valves.—The valves are of steel, the exhaust being Hadfield's New Era D.T.D. 49A and the inlet S. 62. The exhaust valve seat is Stellited, a process which is found to be essential when running engines on a fuel containing tetra-ethyl lead. The ends of both the exhaust and inlet valve stems are also Stellited in order to withstand wear. Both valves have tulip-shaped heads, that of the inlet being slightly larger in diameter. Double concentric valve springs are fitted between the flange of the guide and the valve stem collar which in turn is held in position on the valve with taper split collets.

Timing Gears.—These are housed in the rear cover which is itself held by studs and nuts to facings provided at the rear of the crankcase and top cover. The gear fitted to the rear end of the crankshaft meshes with two spur wheels, situated one above and the other below the centre line of the crankshaft. The upper spur wheel drives a short shaft which has fitted to it a bevel gear, which in turn drives, by means of two more bevel gears, the Eclipse vacuum air pump on the left-hand side of the rear cover, and the governor for the constant speed type of airscrew on the right-hand side. The lower spur wheel drives the camshaft and in conjunction with the vernier enables the valve timing to be adjusted. The gear type oil pump is bolted to a facing on the lower part of the rear cover, and carries a spur gear which meshes with the camshaft gear. Bolted to an extension of the intermediate gear is a skew gear which drives a similar gear mounted on a short transverse shaft below. This shaft, the ends of which are mounted in ball bearings housed in the sides of the rear cover, has a flexible vernier coupling fitted to each end to drive a magneto. The magnetos are bolted on external brackets which are part of the rear cover, and are arranged so that the contact breakers and distributors point outwards, thus permitting easy adjustment and inspection. The starboard magneto is fitted with an impulse starter which delivers a powerful spark at low engine revolutions and thereby facilitates starting.

Lubrication.—(Figs. 9 and 10.) The oil pumps and filters form detachable units bolted to the rear cover. A gear type pump draws oil from a separate tank and delivers under pressure to an Auto Klean filter, which ensures the removal of the finest particles of foreign matter before passing the oil into the engine. A fine gauze filter protects the suction side of the pressure pump. The main oil pressure is regulated to 40 to 45 lbs./sq. in. by a relief valve. From the pressure filter the oil is forced to the main oil gallery which is fitted to the inside of the crankcase. This gallery admits oil to the five main bearings. From main bearings Nos. 1 and 4 oil is forced through the journals and adjacent webs into the hollow crankpins which supply the big end bearings. Holes are drilled in the big end bearings and connecting rod caps, from which oil is thrown on to the cylinder walls and pistons. This arrangement is particularly useful on starting, as proper lubrication of the pistons is established during the first revolutions of the engine; moreover, the supply of lubricant to the cylinder walls is not affected to a large extent by wear of the bearings.

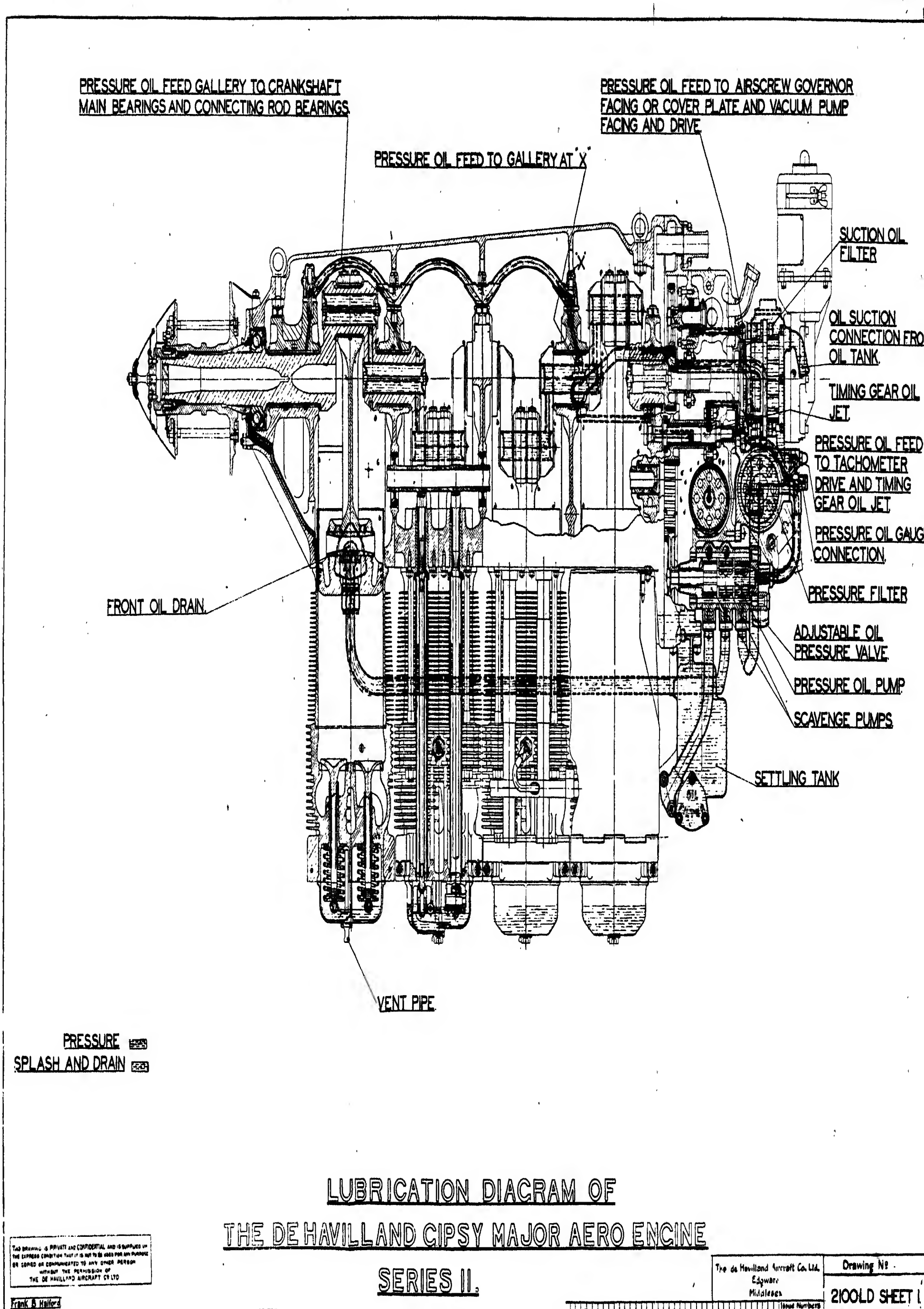

PRESSURE OIL FEED GALLERY TO CRANKSHAFT MAIN BEARINGS AND CONNECTING ROD BEARINGS
PRESSURE OIL FEED TO GALLERY AT "X"
PRESSURE OIL FEED TO AIRSCREW GOVERNOR FACING OR COVER PLATE AND VACUUM PUMP FACING AND DRIVE
X
SUCTION OIL FILTER
OIL SUCTION CONNECTION FROM OIL TANK
TIMING GEAR OIL JET
PRESSURE OIL FEED TO TACHOMETER DRIVE AND TIMING GEAR OIL JET
PRESSURE OIL GAUGE CONNECTION
PRESSURE FILTER
FRONT OIL DRAIN
ADJUSTABLE OIL PRESSURE VALVE
PRESSURE OIL PUMP
SCAVENGE PUMPS
SETTLING TANK
VENT PIPE
PRESSURE
SPLASH AND DRAIN
LUBRICATION DIAGRAM OF
THE DE HAVILLAND GIPSY MAJOR AERO ENGINE
SERIES II.
The de Havilland Aircraft Co. Ltd. Edgware Middlesex
Drawing No.
2100LD SHEET I
Issue Numbers
Frank B Halford

Fig 9.

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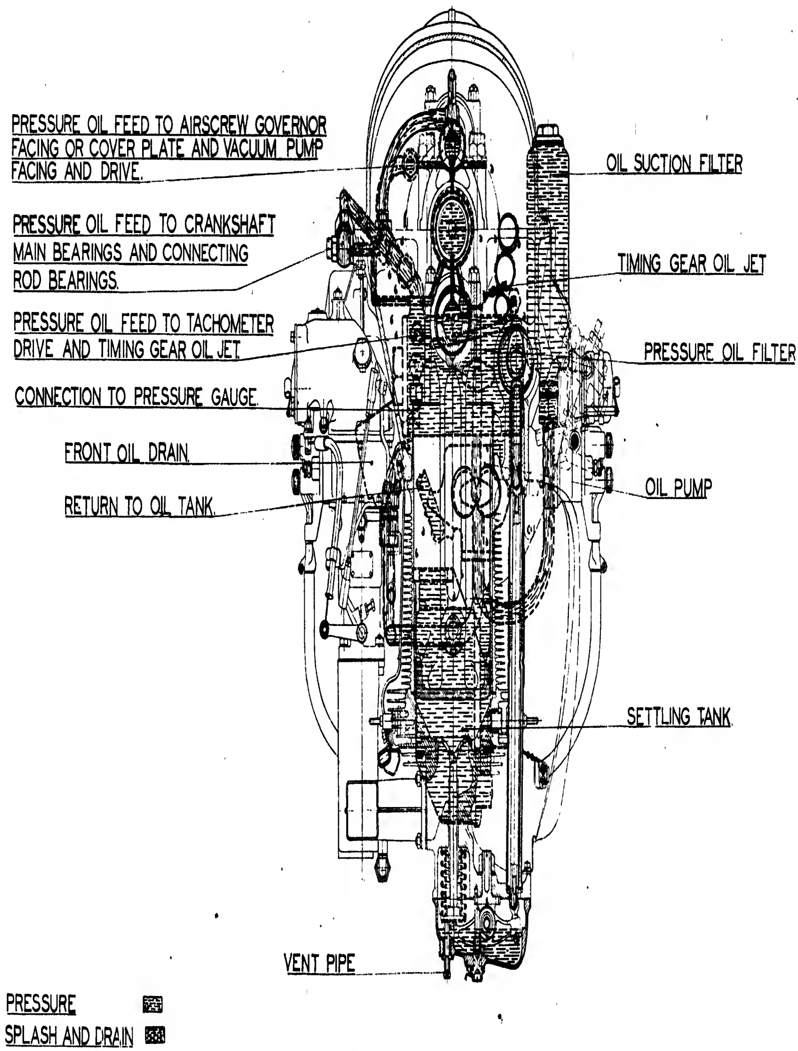


LUBRICATION DIAGRAM OF
THE DE HAVILLAND GIPSY MAJOR AERO ENGINE.
SERIES II.

The de Havilland Aircraft Co. Ltd
Edgware,
Middlesex.

Drawing No.
2100 L.D. SHEET 2

Issue Numbers.

Frank B. Halford.

The spray thus created inside the crankcase serves to lubricate the cams and tappets, and as a good deal of it ultimately comes into contact with the walls of the top cover, a useful oil cooling effect is obtained after it has passed through the engine. The oil then collects in the sump space formed by the extension of the cylinders inside the crankcase. Oil so

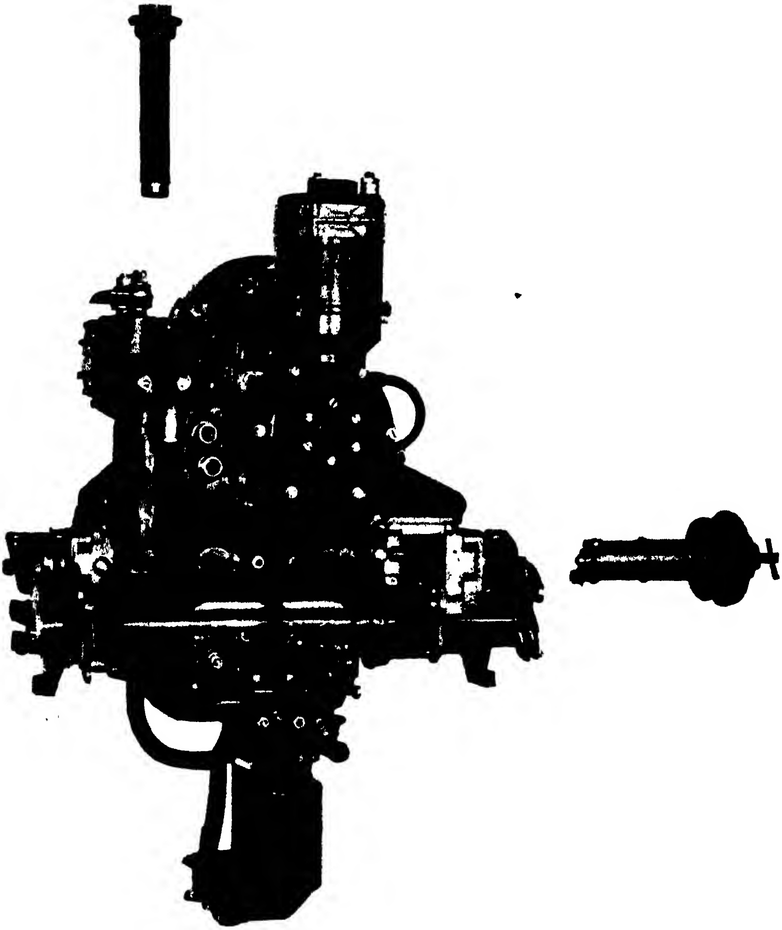


Fig. 11.—External View of Rear Cover.

collected at the front of the engine is scavenged by means of the second scavenge pump, from a cast elektron filter box bolted to the front end of the crankcase, via an external steel oil pipe. The oil collected at the rear of the engine drains through a hole in the front face of the rear cover to an external vertical "settling tank," from which it is drawn by the first scavenge pump and so back to the tank. These pumps are arranged in tandem with the pressure pump, and each is provided with a detachable suction

filter of fine mesh gauze. In the pressure filter casing, connections are provided for two pipes, the upper one of which supplies oil to the revolution indicator drive shaft bushes and thence to a jet which delivers on the pitch line of the magneto drive skew gears, and the other to the oil pressure gauge. The magnetos fitted are of the ball bearing type, the bearings of both armature and distributor spindles being packed with high melting-point grease, sufficient to last 750 hours flying. A frequent application of anti-freezing oil should be given to the impulse starter mechanism through the hole in the side of the casing.

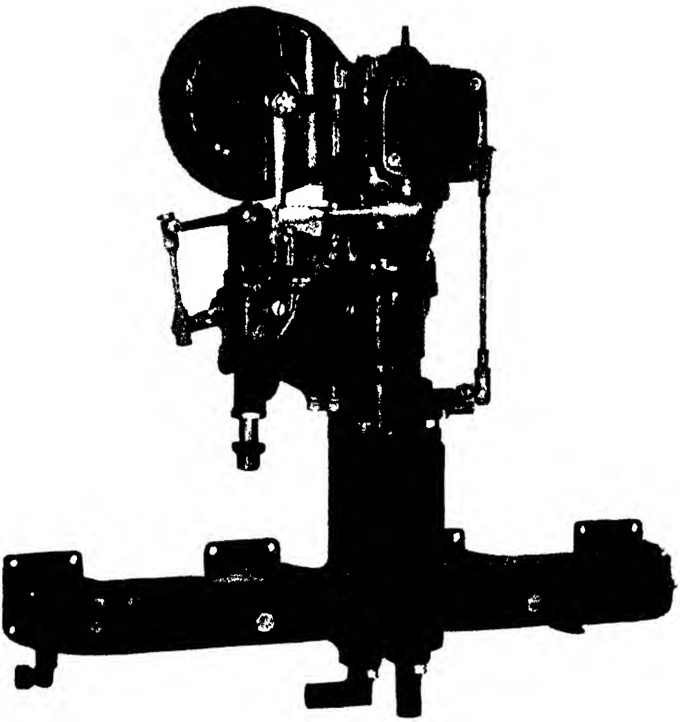


Fig. 12.—Carburettor and Induction Pipe.

Oil Filters.—The oil filters are contained in elektron castings attached to the rear of the rear cover by studs and nuts. The vertical filter is installed on the suction pipe line, and the horizontal filter on the pressure side of the oil pump.

The filters are accessible for cleaning by unscrewing the large hexagonal caps. As the pressure filter is of the Auto Klean type it is only necessary to dismantle the filter for cleaning after every 250 hours' flying. The external handle, however, should be turned frequently in order to clear the filter.

Induction System.—A square section welded steel manifold is bolted to the inlet port facings on the cylinder heads. The main trunk runs upwards from the manifold and finishes with a welded flange to which is bolted the carburettor. The trunk and central portion of the manifold have a square section jacket welded on. Two connections are provided at the base of this jacket, and hot gases are fed in from the exhaust system. The inside of the jacket has baffles to ensure that the maximum amount of heat is extracted before the gases are allowed to escape through the outlet connection. The air for combustion is drawn into the carburettor through a special air intake designed to avoid all freezing troubles, without adverse effects as regards maximum power. Under normal cruising conditions when freezing is most likely to occur, hot air is taken from the vicinity of the cylinders and led through a flame trap direct to the carburettor. In this way a warmed induction is obtained, resulting in smoothness and economy of operation. When, however, maximum output is required, the resistance of a flame trap and the high induction temperature would somewhat reduce the horse-power obtainable.

Under these circumstances, therefore, a throttle operated valve closes communication between the flame trap and the carburettor and at the same time opens a duct communicating with the slip stream through a normal external type of air intake.

Carburettor.—A down draught carburettor Claudel Hobson Type A.1.48 is fitted as standard. It provides a mixture control for correcting fuel mixture at altitude and for economy when cruising.

Fuel Pumps.—Dual D.H.A.C. petrol pumps are optional equipment and are required on most installations. The dual pumps, of the diaphragm type, are arranged as one assembly and bolted to faces provided on the crankcase, the diaphragms being operated off the camshaft through a rocker arm in the construction of the pump, as follows (Fig. 13) :—

By revolving shaft (G), the eccentric (H) will lift rocker arm (D), which is pivoted at (E) and which draws the pull rod (F) together with diaphragm (A), held between metal discs (B), downwards against the spring pressure (C), thus creating a vacuum in pump chamber (M).

Fuel from the tank will enter at (J) into sediment bowl (K) and through strainer (L) and suction valve (N) into pump chamber (M). On the return stroke, spring pressure (C) pushes diaphragm (A) upwards, forcing fuel from chamber (M) through pressure valve (O) and opening (P) into the carburettor.

When the carburettor bowl is filled, the float in the float chamber will shut off the inlet needle valve, thus creating a pressure in pump chamber (M). This pressure will hold diaphragm (A) downwards against the spring pressure (C) and it will remain in this position until the carburettor requires further fuel and the needle valve opens. The rocker arm (D) is in two pieces, the outer operating the inner one by making contact with pin (R) and the movement of the eccentric (H) is absorbed by this " break " when fuel is not required.

Spring (S) is merely for the purpose of keeping rocker arm (D) in constant contact with eccentric to eliminate noise.

All pumps are fitted with a hand primer. Operation of the lever of this pulls the pull rod (F) together with diaphragm (A), so priming the carburettor with fuel for starting the engine.

A gland is fitted round pull rod (F) to stop any fuel which may leak through diaphragm (A) from running into the engine. An adaptor is fitted into the wall of the chamber immediately below the diaphragm. A drain pipe should be connected up to this adaptor, so leading any leakage clear of the aircraft cowling.

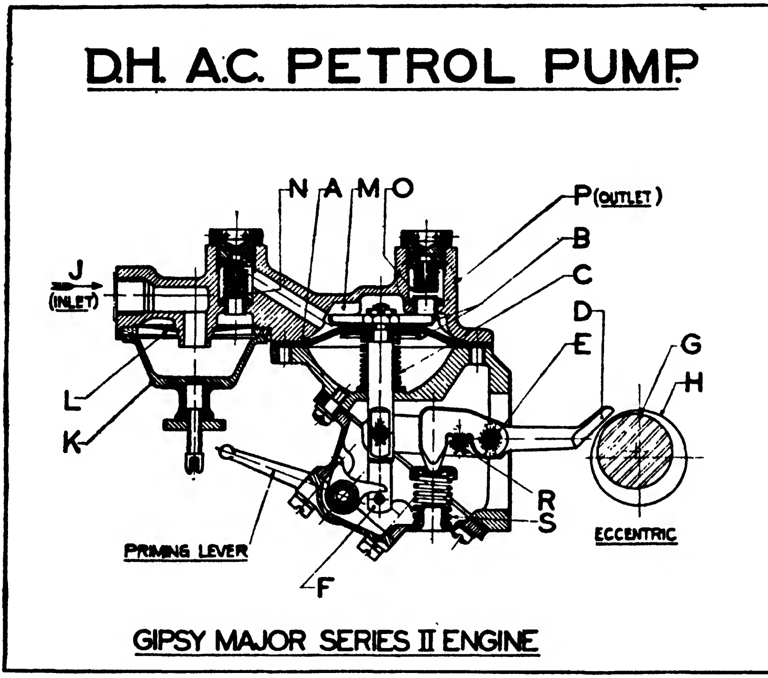


Fig. 13.

Magnetos.—Two unscreened B.T.H. type A.G. 4-4 magnetos are fitted as standard. One magneto has a Z type impulse starter.

Screened magnetos of the same type can be fitted, if required, in connection with radio installations.

INSTALLATION AND STORAGE.

Engine Mounting.—Four vertical facings are provided on the sides of the crankcase for the attachment of the engine feet. A turned recess is provided in each of these facings and the engine foot spigot fits into this recess so that the shear load is taken off the four studs provided for fixing the engine feet. The feet are arranged for a trunnion fixing, and should be mounted in the D shaped rubber blocks which the de Havilland Aircraft Co. Ltd. can supply on application. The red rubber blocks as fitted to the engine feet, are for transport purposes only, and on no account must be used in the aircraft installation.

Cooling System.—The engine will normally be enclosed by the nose cowling when installed in the aeroplane, and cooling has therefore to be arranged by special scoops and baffles. The standard airscoop supplied is fitted on the left-hand side of the engine beneath the aeroplane cowling. The airscoop is attached by hinge pins to plate extensions on the top of the valve rocker casings and the base of the crankcase respectively. The scoop is bowed and slopes towards the cylinders to the rear, its distance therefrom decreasing slightly from front to rear.

Baffle plates are fitted to the cylinders on the right-hand side of the engine in order to deflect the air around the lee side of the cylinder barrels and so obtain the maximum amount of cooling. The baffles are attached by a hinge pin to a bracket on the crankcase and to clips under the cylinder holding down nuts. It should be noted here that the cooling system should be such that the maximum cylinder head temperature measured on the climb should not exceed 220°C.

Fuel System.—The joints of the fuel pipe between the aircraft and the engine can be made by A. M. type metal couplings or brazed nipples and union nuts. Where the fuel.pipe crosses from the aircraft structure to fuel pump or carburettor a flexible pipe such as Superflexit must be used. All pipes, filters and cocks, should have a clear bore of not less than ⅜ in. diameter. Where rigid fuel pipes are used, these should be well supported so that no vibration is set up, caused by their own weight. Under no circumstances should the depression on the inlet side of the fuel pump, caused by restriction or low fuel tank position, exceed 1½ lbs. Should this figure be exceeded troubles will probably be experienced through gas locks in the fuel pumps. The amount of depression which can be put on the fuel before the formation of gas commences is affected by temperature, altitude and the individual vapour pressure of the fuel.

Should it be intended to operate the aircraft under conditions which tend to the formation of gas, depression on the fuel pump inlet should be kept to the absolute minimum, even less than the figure quoted above, if at all possible.

D.H.A.C. Petrol Pump.—The pumps deliver the fuel directly to the carburettor and no reserve supply is necessary. Special precautions are necessary when fitting the suction piping on installations using fuel pumps, as air leaks, which are difficult to detect, are a possible cause of engine failure.

Ignition System.—The earthing terminals on the magneto contact breaker covers should be connected up to a standard twin-knob switch

and labelled to enable the magnetos to be earthed independently, as required. It is important that the common earth connection on the switch be wired directly to some part of the engine and not to the airframe. To ensure safety to personnel when starting the engine by swinging the airscrew, check the L.T. earthing wires for continuity occasionally, using, if available, the standard magneto synchroniser as a continuity tester. Alternatively the check can be made by using an electric torch or hand lamp with a length of flex connecting from the earthing spring on the magneto to the switch at the cockpit. Removal of the magneto contact breaker covers will be necessary, which renders the earthing switches inoperative. This is dangerous, as action of the impulse starter may start the engine should the airscrew be turned. In no circumstances should these tests be made without either (*a*) disconnecting all the H.T. leads from the sparking plugs or (*b*) removing the distributors from the magnetos. After completing the test leave both switches in the " OFF " position.

Oil System.—A nut and nipple for the attachment of a pipe leading to the 0 to 60 lbs./sq. inch pressure gauge or, alternatively, a post suitable for the fitting of a Negretti and Zambra transmitting oil pressure gauge, is provided on the pressure oil filter casing. When nut and nipple are used, an approved gauze covered petrol resisting rubber connection should be provided on the pipe as close as possible to the fitting on the gallery, to take up vibration. This type of connection is preferable to a coiled pipe, as the coils are liable to vibration trouble, due to their own weight. The oil delivery pipe to the engine is connected to the top elbow in the oil suction filter unit, using a P.R. rubber connection; this pipe should be at least $\frac{7}{8}$ in. diameter bore. The oil return pipe from the engine is connected to the $\frac{5}{8}$ in. outside diameter hose connection situated below, and slightly to the right of the oil pump unit, using a P.R. rubber connection. The pipe being at least $\frac{5}{8}$ in. diameter bore. A 1-inch diameter hose connection is attached to the rear of the rear cover to which the breather pipe must be attached. Directly below the above-mentioned is a $\frac{5}{8}$ in. outside diameter brass hose connection which must be connected to the air space above the oil in the tank. As the engine is equipped with dual scavenge pumps, the position of the oil tank is comparatively unimportant. Should the oil tank be very much above the oil inlet level, it may be necessary to provide a cock which can be shut off when the engine is standing to stop oil from draining from the tank to engine. This cock should be interconnected with the fuel cock, to avoid the possibility of the engine being run with the oil cock off. Provision can be made in the inlet and outlet pipes, to and from the engine respectively, for the usual oil thermometer pockets, which must be fitted within 10 inches of the engine itself.

Engine Controls.—Engine control levers in the cockpit should be connected up to the pick-up levers provided on the left-hand side of the engine cross shafts, or to pulleys should the aeroplane be fitted with pulley operated throttle and mixture controls. It is important that the controls in the cockpit give slightly more than sufficient movement in order to give full travel to the controls on the engine; this will ensure that the controls will be brought up positively against the stops on the carburettor. The throttle and magneto controls are interconnected in such a way that when the throttle is closed, the ignition is fully retarded. As the throttle travels through the first part of its movement, the ignition is fully advanced,

where it stays throughout the whole of the cruising range. When a de Havilland two-pitch airscrew is fitted, a control must be fitted up between the cockpit and the oil cock operating lever, at the rear of the oil pump casing. If a constant-speed airscrew is fitted, a control must be fitted up between the pulley on the governor and the cockpit.

Storage.—Engines not required for immediate use should be stored with cylinders upwards and maintained by frequent oiling through the sparking plug holes and by turning the crankshaft.

STARTING AND RUNNING.

Before Starting.—Before starting the engine for the first time, it is advisable to check the following points :—

(1) Ensure that all oil injected into the cylinders for the purpose of storing is allowed to drain out of the exhaust ports, by turning the crankshaft so that each exhaust valve is allowed to stand open for a small period.

(2) See that sufficient fuel is in the tank.

(3) See that sufficient oil is in the tank and valve rocker covers.

(4) Check the Magneto L.T. earthing brushes, wires and switches for continuity, correct connections and functioning by using the standard magneto synchroniser as a continuity tester. Alternatively the check can be made by using an electric torch or hand lamp with a length of flex connecting from the earthing spring on the magneto to the switch at the cockpit. Removal of the magneto contact breaker covers will be necessary, which renders the earthing switches inoperative. This is dangerous, as action of the impulse starter may start the engine should the airscrew be turned. **In no circumstances should these tests be made without either (a) disconnecting all the H.T. leads from the sparking plugs, or (b) removing the distributors from the magnetos.** After completing the tests, leave both switches in the " OFF " position.

(5) Check over the tightness and locking of all bolts, nuts, etc., on the engine and mountings.

(6) Operate all engine controls to see that these work freely and give full movement to the throttle, magnetos, etc.

(7) Check the connection of the oil pressure gauge pipe.

(8) Check the connections of the revolution indicator.

(9) Check all cowlings and fixings and locking of draw wires, etc.

(10) Turn on fuel and check for leaks.

(11) Turn the engine over to check the clearance between the airscrew spinner and cowling.

(12) Check the position of the impulse break. The audible click given by this mechanism should take place when the airscrew blade is between 30° and 45° before the lower vertical position. If the engine is fitted with hand-starting gear, the position of the impulse break in relation to the airscrew is not of importance.

(13) Prime suction oil filter.

Starting.

NOTE.—During arctic weather conditions no attempt should be made to start the engine until the oil has been warmed.

Starting by Swinging the Airscrew.—See that both magneto switches are " OFF." Flood the carburettor by depressing the spring plunger provided in the top section of the float chamber of the carburettor.

The fuel pump priming levers will have to be operated while the spring plunger on the carburettor is depressed by means of the small wire led to the port side of the engine. Open the throttle very slightly and pull the engine over not more than four or five compressions. Increase the opening of the throttle slightly, after putting the right hand or impulse magneto switch in the " ON " position ; pull the airscrew sharply over compression.

The engine should then start. If the weather is hot do not pull the airscrew over to suck in, but flood the carburettor slightly, and start at once.

If the engine is hot do not flood the carburettor at all, as the mixture under these conditions may easily become too rich.

Starting with an Electric Starter.—The same instructions as given in "Starting by Swinging the Airscrew" can be generally applied. In this case, however, instead of pulling over four or five compressions, motor the engine for a few revolutions.

Starting with a Hand-Starting Gear.—The same instructions as given in "Starting by Swinging the Airscrew" can be generally applied. In this case, however, instead of pulling over four or five compressions, turn the engine for a few revolutions.

After Starting.—If oil pressure does not show between 30 and 40 lbs./sq. inch, within one minute, shut down engine and investigate cause. Possible causes are :—Air leaks in suction oil pipe, or suction filter connections ; pump requires priming, defective oil pressure gauge, or choked pipe to gauge. When oil pressure is satisfactory, run engine at 800-900 R.P.M. for at least four minutes to allow the oil to warm up and circulate freely. The oil temperature will probably not show on the thermometer but it may be assumed that after this run the oil temperature and circulation will be satisfactory, and the engine can be opened up to full throttle to ascertain the ground R.P.M. The running of the engine at full throttle on the ground must be carried out with a certain amount of discretion and under no circumstances should the full throttle running exceed a period of 30 seconds, or less in tropical climates.

It should be observed that this full throttle running is only for the purpose of obtaining the ground R.P.M. and not for the purpose of warming up.

The running of the engine should be checked on each magneto. Revolutions per minute will probably drop slightly, but engine should run smoothly and evenly on each magneto. Check magnetos with engine running between 1600 R.P.M. and full throttle.

Oil pressure under these conditions should be between 40-45 lbs. per sq. inch. Revolutions on the ground will vary with the different airscrews fitted, but will probably be between 1900 and 2050 per minute with a fixed pitch airscrew.

Possible Causes of Failure to Start.

(1) Cold or hot weather. In cold weather it is almost impossible to get the mixture too rich. In hot weather, too rich a mixture is most likely the cause of the engine not starting. If the latter is the case, open the throttle wide and motor or swing the engine over for several revolutions, with the switches "OFF."

This will clear the engine, which should then be started by following the instructions in previous section headed "Starting."

(2) Carburettor slow-running jet choked.

(3) Water in the carburettor. Remove the main and power jets, and flush the carburettor through by turning the fuel cock "ON."

(4) Impulse starter not working properly. When the engine is turned there should be an audible click from the impulse starter on the right-hand magneto near the inner dead centre position of any piston.

The actual arrest and rotation of the magneto armature after release can be observed by removing the right-hand magneto contact breaker cover. The earthing switch for the magnetos will now be inoperative. This is dangerous, as action of the impulse starter may start the engine when turning the airscrew. **In no circumstances should this Inspection be made without (a) disconnecting all the H.T. Leads from the sparking plugs, or (b) removing the distributors from the magnetos.**

(5) Sticking caused by end pressure exerted on the impulse starter units, owing to swelling of the flexible vernier couplings, which may occur through oil coming into contact with them. To rectify, slacken the holding down screws of the magnetos and ease the latter slightly away until the flexible coupling is just gripped when fully engaged.

(6) Non-operation of the mechanism through congealed oil, or lack of lubrication. Flush out with paraffin and lubricate with anti-freezing oil. If, after making the above adjustments, failure still persists, replace the magneto with a new one.

(7) Contact breaker rocker arm stuck open. This may be due to (*a*) a weak or broken contact breaker spring, or (*b*), tightness of the contact breaker rocker arm bush. After rectifying the cause of the trouble the bush should be very slightly lubricated before re-assembly.

(8) Damp atmosphere. If the engine has been standing in a damp atmosphere, it may be necessary to wipe the insulators of the sparking plugs and the distributors of the magnetos before a start can be made, to reduce the surface leakage of H.T. current, which takes place under these conditions. (When the engine is fitted with a screened ignition equipment, this does not apply).

Possible Troubles.—(1) Misfiring. Should any one cylinder misfire or cut out when running locate the defective sparking plug and clean, or fit a new one.

(2) Engine misfiring on one magneto. Check and test all plugs and magnetos. If the trouble is traced to a magneto or distributor, and no fault can be detected which can be readily rectified, it should be returned to the manufacturers. If the engine does not fire at all on one magneto, examine the switches and low tension wiring (see previous paragraph headed " Ignition System ") as well as the magneto, also ensure that the high tension leads are connected up to their correct terminals on the magneto distributors.

(3) Engine cutting out in flight. Make sure that the switches have not been switched " OFF " accidentally. Test the engine on separate magnetos, as a fault in one magneto or distributor may upset the running of the engine.

(4) Low oil pressure. This may be due to air leaks, or air locks in the suction pipes, choked filters, stuck release valve, defective pressure gauge or its pipe line choked.

Rough Running.—(1) Airscrew out of balance. If possible, check engine with a different airscrew. When a fixed pitch wooden airscrew is being refitted to the engine, see that the bore of the airscrew is a snug fit on the locating land of the boss. The bolts should be tightened up evenly, and the track of the blades measured at the tips should not differ by more than $\frac{1}{8}$ inch. If a de Havilland C.P. or Constant Speed Airscrew is fitted, reference should be made to the Airscrew Handbook.

(2) Tappets out of adjustment. Reset to the standard clearances.

(3) Sparking plugs, dirty or badly adjusted. Clean, reset the gaps and test, if possible under pressure, before replacing.

(4) Magneto contact breakers dirty, or incorrectly adjusted. Clean and re-adjust.

(5) Engine mounting, or holding down bolts loose. The rubber blocks may be incorrectly fitted. (See notes under "Engine Mounting" in section on "Installation.")

(6) Compressions uneven. If the compression of any cylinder is very weak, first check the tappet clearance, and if necessary remove the head and cylinder, and investigate the cause. Probable causes are:—Stuck piston rings, leaky valves, or defective head joint washers.

(7) Air leaks in induction system. Inspect and test the induction manifold for leaks. Inspect the cylinder port washers and carburettor joint washers for tightness.

Low R.P.M. on Ground.—If all the parts of the engine are in order and the engine is running well, low engine R.P.M. may result from the use of an unsuitable airscrew. Another airscrew of checked correct Drawing No. should be substituted. When a de Havilland controllable pitch airscrew is fitted, low R.P.M. may be caused by too coarse a pitch, which should be set according to the airscrew handbook.

Cold Weather Difficulties.—Using oil of too heavy a grade. If a heavy grade of oil is in use, it will be an advantage to pre-heat, especially if the engine has been standing out in the cold for any length of time.

ENGINE—AIRSCREW FLIGHT PERFORMANCE. (Figs. 14, 15).

The accompanying graphs CD.6126 and CD.6125 show respectively the comparative outputs available for cruising, and for take-off and climb when fixed-pitch and controllable-pitch airscrews are fitted to the Gipsy Major, Series II., engine.

(a) **The Fixed Pitch Airscrew** absorbs the full-throttle power developed by the engine at the maximum permissible R.P.M. (2,400 R.P.M.) in level flight at sea level.

The cruising output (curve A. CD. 6126) is determined by the amount of throttling necessary to obtain 2,100 R.P.M. (the maximum R.P.M. for continuous cruising) and by the reduced atmospheric density at higher altitudes.

The climbing output (curve A. CD. 6125) represents the power developed by the engine, full throttle at 2,100 R.P.M. (the maximum climbing R.P.M.) at any altitude.

The take-off output (curve A. CD. 6125) for the purpose of these comparisons is defined as the mean between the value obtained with the machine on the ground and the engine running full throttle, and that with the machine having attained full climbing speed in flight.

(b) **A Two-Pitch Controllable Airscrew intended for effective Operation at relatively low altitudes** is designed to absorb, when in its coarse pitch position, the power developed by the engine at 2,100 R.P.M. at 3,000 feet, when throttled until the induction pipe pressure is reduced to 11.7 lbs./sq. inch absolute.

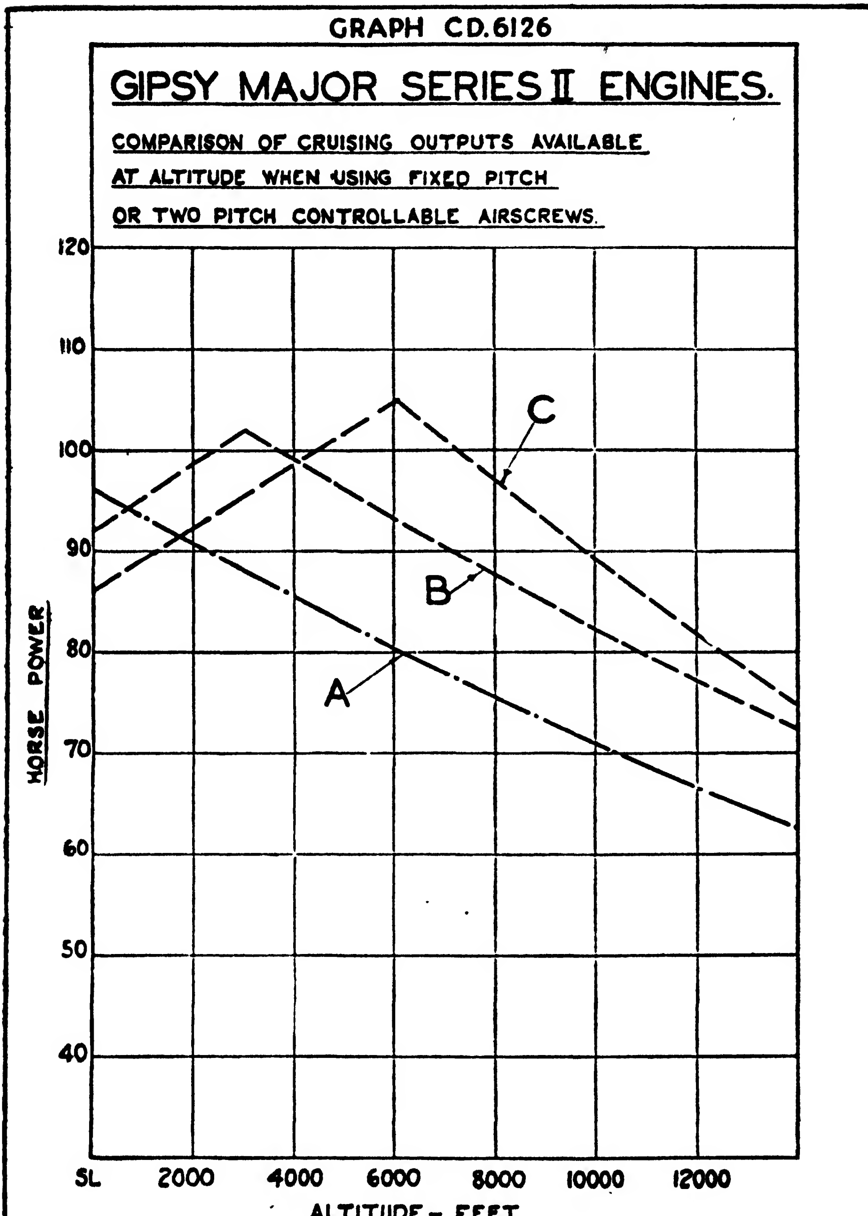

GRAPH CD.6126
GIPSY MAJOR SERIES II ENGINES.
COMPARISON OF CRUISING OUTPUTS AVAILABLE
AT ALTITUDE WHEN USING FIXED PITCH
OR TWO PITCH CONTROLLABLE AIRSCREWS.
HORSE POWER
120
110
100
90
80
70
60
50
40
A
B
C
SL
2000
4000
6000
8000
10000
12000
ALTITUDE – FEET.

Fig. 14.

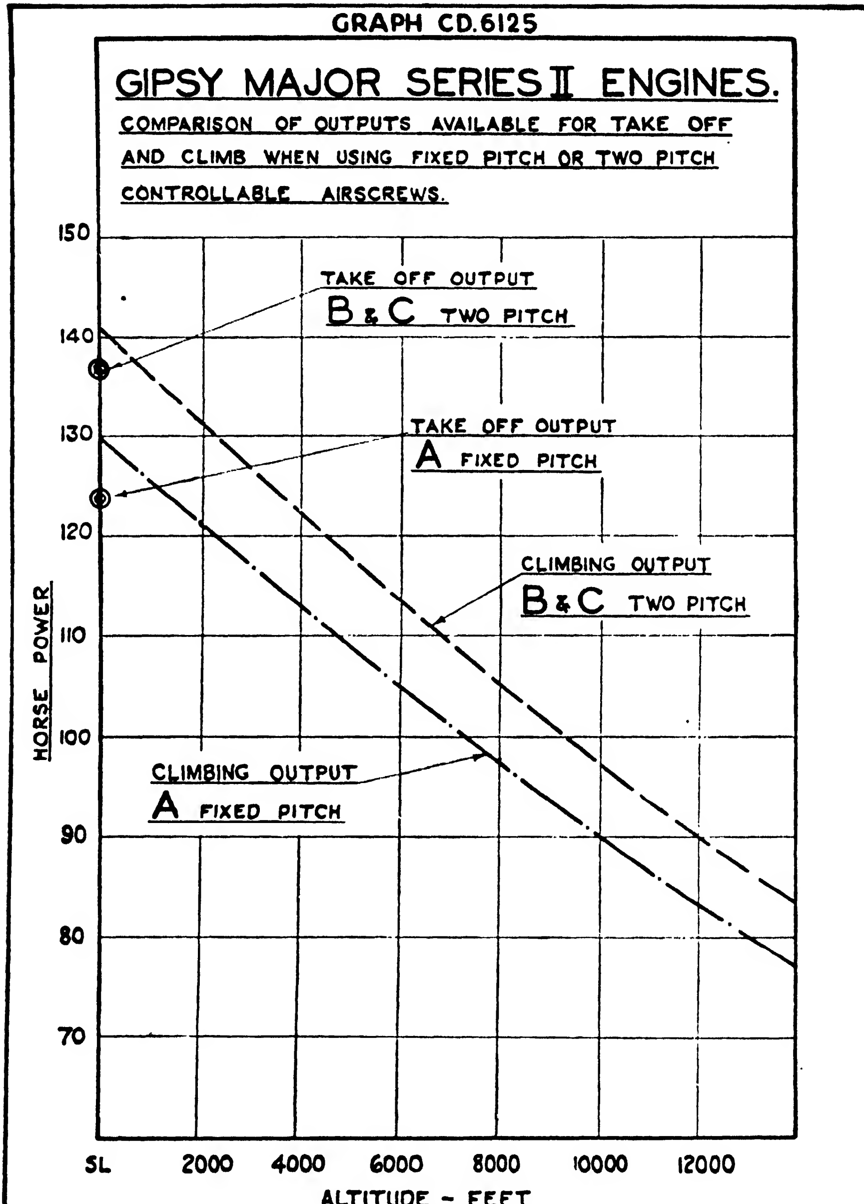

GRAPH CD.6125
GIPSY MAJOR SERIES II ENGINES.
COMPARISON OF OUTPUTS AVAILABLE FOR TAKE OFF AND CLIMB WHEN USING FIXED PITCH OR TWO PITCH CONTROLLABLE AIRSCREWS.
TAKE OFF OUTPUT
B & C TWO PITCH
TAKE OFF OUTPUT
A FIXED PITCH
CLIMBING OUTPUT
B & C TWO PITCH
CLIMBING OUTPUT
A FIXED PITCH
HORSE POWER
150
140
130
120
110
100
90
80
70
SL
2000
4000
6000
8000
10000
12000
ALTITUDE - FEET.

Fig. 15.

The cruising output with this airscrew is given by curve B of CD. 6126. Below 3,000 feet altitude the output is limited by restricting the induction pipe pressure to 11·7 lbs./sq. inch absolute, and with the engine throttled to this extent, the R.P.M. will fall slightly below 2,100 R.P.M. Above 3,000 feet altitude, the limitation is that imposed by throttling to the maximum cruising R.P.M. of 2,100.

The climbing output (curve B of CD.6125) represents the power developed by the engine full throttle at 2,400 R.P.M. at any altitude; the fine pitch position of the airscrew being designed to absorb this output.

The take-off output is, as with Airscrew A, the mean between machine static and full climbing flight.

(c) **A Two-Pitch Controllable Airscrew intended for effective Operation at Altitudes in excess of 5,000 feet** is designed to absorb, when in its coarse-pitch position, the power developed by the engine at 2,100 R.P.M. at 6,000 feet with induction pipe pressure at 11·7 lbs./sq. inch absolute; this is approximately full throttle.

The cruising output with this airscrew is given by curve C or CD.6126. Below 6,000 feet altitude the output is limited by restricting the induction-pipe pressure to 11·7 lbs./sq. inch absolute, and, with the engine throttled to this extent, the R.P.M. will fall below 2,100 R.P.M. slightly at altitudes approaching 6,000 feet, but by an appreciable amount at very low altitudes. Above 6,000 feet the engine operates at full throttle at approximately 2,100 R.P.M.

The climbing and take-off outputs with this airscrew are exactly as for airscrew B (see curve CD.6125).

The outputs shown on these curves take no account of the effect of forward speed. In flight when a well-designed forward-facing air-intake is fitted, the effect of the velocity of the intake air is to increase the altitude to which 11·7 lbs./sq. inch absolute induction-pipe pressure is maintained, from 6,000 feet to about 7,000 feet; and, further, to result in a small increase in power when operation is at full throttle.

The curves CD.6125 and 6126 show at a glance the advantages to be obtained from using de Havilland controllable-pitch airscrews on the Gipsy Major Series II. engines, and the different effects obtainable from alternative pitch settings.

Thus, with a conventional fixed-pitch airscrew (curve A), the cruising performance at altitude is seriously limited by what is really an unnecessary throttling of the engine, in order to hold the speed at 2,100 R.P.M. The two-position controllable airscrew C makes the most use of the engine at high altitudes, and shows improved performance over airscrew A for altitudes above 2,000 feet. The coarse pitch of airscrew C entails some loss in cruising speed below 2,000 feet.

The operator who does most of his flying at 5,000 feet or below would be well advised to fit an airscrew similar to B. This combination may be regarded as a compromise between fixed-pitch airscrew A and coarse-pitch airscrew C.

Curve CD.6125 demonstrates very forcibly the improvements in take-off and climb obtained by the use of controllable-pitch airscrews on the Series II. engine. Actually, the improvement is even greater than that indicated by the curves since, with most modern machines, the conventional fixed-pitch airscrew is seriously stalled at take-off. In other words, the im-

provement in effective thrust from using controllable airscrews is greater than the comparison of engine power suggests.

It will be noted that it is necessary to regulate the cruising output to an induction-pipe pressure in the case of all controllable-pitch airscrews. For this purpose it is essential to provide a "boost gauge" for each engine as standard aeroplane equipment. Throttling to the prescribed induction-pipe pressure when cruising, avoids the danger of over-loading the engine.

COMPLETE OVERHAUL.

Dismantling, Inspection, Re-assembly, Testing.

Removal of Fixed Pitch Airscrew and Hub.—Remove the split pin and slotted nut at the front of the spinner, which will allow the spinner to be pulled off. Unscrew the four cheese head screws and remove the locking plates. Using box spanner (Part No. T.800-50 and tommy bar T.800-71) unscrew the crankshaft front nut. As this nut is unscrewed, the aluminium bronze cone at the front of the boss will be pulled forward up against the withdrawal nut, so pulling the hub, together with the airscrew, from the splines of the crankshaft.

Removal of Controllable Pitch and Constant Speed Airscrews.—If a de Havilland Controllable Pitch or Constant Speed Airscrew is fitted, it must be removed according to the instructions given in the airscrew handbook.

Removal of Engine from Aircraft.—Remove cowling, cold air intake, disconnect fuel pipes, oil pipes, engine controls, remove exhaust manifold using spanner (Part No. T.800-1). Disconnect revolution indicator drive, breather pipe and remove caps which hold engine foot mounting blocks. If an electric starter is fitted, remove leads from starter and, if necessary to clear aircraft structure when engine is being lifted out, remove starter itself by unscrewing the six retaining nuts. The engine should now be slung by the two eyebolts in the top cover, and with the engine still on the sling, fit engine feet if available (Part No. J.526) which are more suitable for bolting to the workshop engine stand, which should itself be of the type suitable for inverting the engine. Remove locking wires, nuts and valve gear covers which contain oil, and then invert engine.

Removal of Induction Manifold and Ignition Equipment.—Remove induction pipe, carburettor and hot-air intake complete as one unit, using universal spanner (Part No. T.800-1) to remove nuts holding induction pipe to cylinder head. Remove distributors with high tension leads by unscrewing the four retaining nuts. Remove cylinder baffles, then sparking plugs, using box spanner (Part No. T.800-18) and tommy bar (Part No. T.800-19).

Removal of Rocker Spindles, Rockers and Tappet Rods.—

(1) Remove the clamping bolts holding the valve rocker spindles in place in the rocker brackets, and using extractor (Part No. T.2200-5) withdraw rocker spindles.

(2) The rockers and tappet rods may now be removed.

(3) Telescope the two halves of the tappet rod casing tube together, and remove from position.

Removal of Cylinder Heads and Barrels.—Loosen all cylinder head nuts, using spanner (Part No. T.800-80). Ease cylinder heads up, as these are being unscrewed, and remove cylinder baffle brackets and nuts. Lift cylinder head clear of studs. Next remove cylinders. These should be eased carefully, with pistons on outer dead centre, supporting the pistons as cylinders are lifted clear ; should the cylinders be stuck in the crankcase, striking them sideways alternately with the palm of the hand should loosen them.

Removal of Pistons.—Remove circlips from one end of each gudgeon pin, using the circlip extractor (Part No. T.1300-830/3). Care should be taken to avoid damaging or burring the groove or slot at end of the gudgeon pin, during this operation. If a burr is accidentally raised, stone it off to prevent scoring of the bore in the piston boss and connecting rod small end, during removal of the gudgeon pin. After removal of the washers, the gudgeon pin can be pushed out and the piston removed. If the gudgeon pin is too tight to be removed by hand, it should be extracted by using gudgeon pin extractor (Part No. T.1300-38).

Removal of Rear Cover.—Remove engine controls, and external oil pipes connecting the rear cover to the crankcase. Unscrew the nuts which secure the rear cover to the crankcase and also the bolt placed behind the oil pump outlet to tank. Tap the cover all round with a rubber mallet in order to break the joint and draw cover towards the rear.

Owing to gear tending to foul on the inside it will be necessary to ease the rear cover slightly to the left-hand side, immediately it is clear of the studs. It will be found that the rear cover, oil pumps, magnetos, starter (if fitted), etc., can now be removed as one unit.

Removal of Camshaft Gear, Front Cover and Thrust Race.—Bend the tab back out of the slot in the nut at the rear of camshaft and unscrew nut. Using extractor (Part No. T.800-61) pull off the camshaft gear. To remove the steel front cover, first remove the split pins and then unscrew the five retaining nuts, which will allow the front cover to be drawn off its studs. The thrust race housing together with the thrust race, oil flinger and bronze cone, is now withdrawn, using extractor bolts (Part No. T.1300-93) in the holes provided. While carrying out this operation, great care must be exercised to ensure that the thrust race housing is not distorted, as the rear cone is a tight fit on the shaft. Now remove all nuts and spring washers holding the tappet guides in place.

Removal of Top Cover and Crankshaft Assembly.—Remove the bolts, plain nuts and spring washers which hold the top cover to the crankcase and after breaking joint by lightly tapping all round, lift off the top cover. Remove the nuts and copper asbestos washers, then lift off the oil gallery. Bend back the locking tabs and unscrew the castellated nuts holding the main bearing caps in position. Remove the main bearing caps complete with bearings. Lift the crankshaft complete with connecting rods from the crankcase. Remove the half bearings from the crankcase.

Removal of Camshaft and Tappets.—It will be found better to remove the tappets from the crankcase before attempting to remove the camshaft. After removing the tappet guide retaining nuts and spring washers, the complete tappet can be tapped out of its cover. A fibre drift is recommended for this operation. Next remove the three plain nuts and spring washers holding the camshaft front bearing; this should be removed by using the drift (Part No. T.800-72) and tommy bar (Part No. T.800-71A). Then remove the two split pins, slotted nuts and washers holding the rear camshaft bearing in the crankcase. The camshaft may then be withdrawn towards the rear, together with the rear bearing. Care being taken that the intermediate camshaft bearings are not damaged.

Dismantling of Crankshaft Assembly.—Remove the split pins, castellated nuts and thin steel washers on the connecting rod bolts. Tap back the bolts with a soft drift until they are clear of the caps. Lift off

the caps and half bearings, and lower the rods off the shaft. Remove the split pins and slotted nuts from the bolts in the crankshaft oil seals. Remove the bolts, seals, and copper asbestos washers. Remove split pin and nut on the retaining bolt, holding the crankshaft gear. Remove the retaining bolt. To extract the gear use the extractor (Part No. T.1300-94/1). Place the sleeve of the puller over the gear, see that the flat end rests against the rear side of the crankshaft web. Place the pad in the recess in the front of the crankshaft gear. Enter the bolt through the sleeve, gear pad and nut. By screwing the bolt into the nut, the gear will be withdrawn from the shaft. To hold the nut a short spanner (Part No. T.1300-84) is provided.

Dismantling of Rear Cover.—Remove all external oil pipes. Unscrew the three nuts holding the vertical suction filter into position on the left-hand side magneto platform and remove filter. Unscrew the bolts fixing the magnetos and flexible couplings. Next remove the gear oil jet and delivery pipe. As the small filter in the banjo on the end of the gear jet pipe is easily damaged if allowed to mix with heavier parts, it should be tied in place in the banjo. The hand turning gear, or starter if fitted, should be removed at this stage together with its adaptor. If a starter has not been fitted, remove the four nuts and spring washers, allowing the cover plate to be pulled off its studs. Remove the vacuum pump and airscrew governor, remove the nuts from the drive spindles, using box spanners (Part No. T.2100-1 and T.2100-2). Next remove the lock-wire, unscrew the large cap nut and withdraw the Auto-Klean filter from its casing. Then unscrew the three nuts which attach the filter casing to the rear cover and remove the filter casing assembly complete with cross shafts, etc.

Dismantling of Oil Pump.—Flatten out the tab on the tab washer which is under the nut holding the oil pump driving gear to the spindle. Unscrew the nut and ease the driving gear off the spindle. If the gear is supported and the spindle is lightly tapped, the gear should come off the spindle without much difficulty. The nuts and washers which hold the pump assembly to the rear cover should be removed. The pump assembly can be removed from the rear cover by sliding it out of the spigot in the rear cover and then along the studs. To remove the relief valve, straighten out the tab which locks the hexagonal plug in the oil pump rear cover, unscrew the plug, then the relief valve piston and spring can be withdrawn. The shims for the relief valve adjustment will probably remain in position in the piston, but should they come out, check their number to ensure correct reassembly. If necessary, the pump spindle bronze bushes at the driving end can be removed by tapping out of position with a soft drift, whereas the bronze bush pressed into the blind hole of the oil pump cover must be removed by one of the following methods.

(1) Turn up a plug to be a push fit in the bush and fill the latter with thick grease. Enter the plug in the bush and press or hammer it in, causing the grease to force the bush out of place. This method will be successful providing the bush is not too tight.

(2) Mount the rear cover on the face plate of a lathe and carefully turn out the bore of the bush until only a thin shell remains ; this can be easily pulled, or broken, out of position.

Dismantling of Revolution Indicator Drive, Dual Type.—Remove the eight 5 mm. nuts and spring washers which hold the revolution indicator

drive gear box cover to the rear cover. This gear box cover should then be tapped with a small mallet to break the joint, and it can then be withdrawn from the rear cover, complete with its two spur wheels. Bend back the locking tabs and unscrew the nut holding the main revolution indicator driving spur wheel on its spindle. Remove the spur wheel, woodruff key, and spindle from the rear cover.

Dismantling of Magneto Drive Shaft.—Remove the split pin, nut and bush from the bolt through the centre of the shaft. Remove the bolt and pull out the flexible coupling drives from either side. Remove the four nuts and spring washers holding the oil swirls into place on either side, and pull the swirls off their studs. Tap the steel sleeve which fits the bore of the two ball races from the right hand side. This action will force the ball-race on the left-hand side from its housing. Continue to tap the sleeve until it is clear of the spur wheel allowing this wheel to be lifted from position. It is now a simple matter to remove the remaining ball-races and housings.

Dismantling of Idler Spindle.—Flatten out the tab of the tabwasher under the set screw in the front of the idler spindle. Remove the set screw and washer. To extract the spindle use the extractor (Part No. T.1300-97). Screw the hexagonal part of the extractor on to the threaded part of the idler spindle. Place the sleeve over this part and over the shaft until the end of the sleeve takes a bearing on the boss of the crankcase round the idler spindle flange. Screw the nut on the thread which projects from the sleeve. By tightening this nut the idler spindle can be withdrawn from the crankcase.

Dismantling of Cylinder Heads.—The rockers and spindles have already been removed as described in para. headed " Removal of Rocker Spindles, Rockers and Tappet Rods."

Place the cylinder head over a small block of wood sufficiently thick to allow the valves to be held in place. Depress the valve collar, using a valve spring compressor (Part No. T.1300-78A1). The collets can then be removed from the valve stems. Remove the compressor and withdraw the springs and collars. After lifting the cylinder head off the wooden block, the valves may be withdrawn. To remove the valve guides use extractor (Part No. T.1300-98).

Dismantling of Pistons.—To remove piston rings from piston, stand it on the bench with skirt downwards, commence with top ring and slide all rings upwards, that is towards the crown of the piston.

Inspection of Cylinder Heads.—After cleaning and decarbonising all parts, the following points should be noted during the subsequent inspection :—

(1) Examine the cylinder heads for cracks.

(2) Carefully examine the valves for any sign of pitting or pocketing and also examine Stelliting for cracks. Any signs of picking up or roughness on the valve stems should be smoothed off and polished with a superfine emery cloth. If the valve guides or stems are worn beyond repair tolerances, new parts should be fitted. To avoid damaging the ends of the valve guides on replacement, the soft drift should be used (Part No. T.1300-85/1).

(3) The nut holding the valve rocker bracket should be checked for

tightness and, if slack, tightened up with spanner (Part No. T.2200-11), a new split pin being fitted.

(4) Check the fit of the rocker bush on the spindle. Check the rocker pads for wear. If the wear is only slight, it can be rectified by stoning smooth, but if the contour of the pad is badly effected, a new pad should be riveted into the rocker. Check the cup end in the rocker and the ball on the tappet rod for any signs of pitting or undue wear. If pitted, however, slightly, replace by new parts. Check tappet rods for straightness.

(5) Examine steel valve seatings in cylinder head for movement and cracks.

Inspection of Cylinders and Pistons.—Cylinders and pistons should now be examined. Check the cylinder for wear, ovality and scoring of the bore. The piston should be checked for cracks, wear in the gudgeon pin bores, wear in the ring grooves and wear on the diameter. Piston rings should be checked for blowing by loss of spring, or excessive gap. Insert the piston in the cylinder and use the crown for squaring the rings when checking the gap. Fit the piston ring to the piston for checking the ring groove clearance; before doing this, make sure that the ring grooves are free from carbon. Check the gudgeon pin for wear and cracks, check the fit in the connecting rod and piston.

The rings should be squared and the gaps checked at the extreme outer end of the cylinder barrel, that is, where the bore is the smallest diameter.

Inspection of Connecting Rods.—Check up small end bores for wear and ovality, and the small and big end bores together for alignment. Examine the connecting rod bearings for cracks, scoring and adhesion of the white metal. Assemble on crankshaft and check for clearance and end float. Do not face off the cap to rectify worn bearings; fit new bearings.

Inspection of Crankshaft and Gear.—The crankshaft should be examined for scoring, eccentricity and ovality of the journals and crankpins. If the scoring is deep or if the eccentricity or ovality is outside tolerance limits, the shaft should be reground. The splines where the airscrew fits, should be examined for any signs of damage. If slight burrs are apparent they should be stoned off carefully. (Should engine have been in a crash it will be as well to check up to see that the flange is true with internal splines). Check all gears for chipping, wear or pitting. If chipping is not very pronounced and is confined to the edges of the teeth, these places can be stoned smooth. Gears worn or pitted very badly should be replaced by new. Check the backlash of the various gears.

Inspection of Main Bearings and Caps.—Inspect main bearing caps for cracks and tightness of dowel pins. The main bearings should be inspected for cracks and scoring. Assemble the bearings in the crankcase, and check for clearance on the diameter of the crankshaft. Do not face off the caps to rectify worn bearings; fit new bearings.

Inspection of Crankcase and Camshaft.—Examine the crankcase for general condition and any signs of cracking. Check the tightness of the studs. Check for any signs of flaking of the case or chipped edges on cams and for general condition of the bearings. Any roughness on the edges of the cams should be removed by careful stoning.

Inspection of Crankshaft Thrust Race.—Wash the thrust race thoroughly and examine for any signs of roughness or pitting of the balls or tracks. If defective, however slightly, reject and fit a new bearing.

The period of running of the races forms no guide as to their serviceability, as the bearings are adversely affected by condensation if the engine is allowed to stand idle for long periods.

Inspection of Plain Bearings and Tappets.—Check camshaft plain bearings for tightness of fit and condition. Check the fit of the tappets in the guides and examine the condition of the bearing faces; examine the heel of the tappets for flaking, cracks and contour.

Induction Manifold.—Test for leaks.

Reassembly of Engine.—After all parts have been examined, faulty parts replaced and valves ground in, reassembly should take place in the reverse order to that given for dismantling. The following parts should be replaced by new.

(1) Dermatine rings between cylinder flanges and crankcase.
(2) ,, ,, tappet guide flange and crankcase.
(3) ,, ,, tappet casing tubes.
(4) Copper asbestos washers between cylinder head and barrel.
(5) ,, ,, exhaust ports.
(6) ,, ,, oil pipes and filters.
(7) ,, ,, main bearing feed pipes.
(8) ,, ,, airscrew oil feed pipe banjo.
(9) ,, ,, induction ports.
(10) Klingerit washers between carburettor and induction manifold.
(11) Hallite joint. Breather connection-timing gear cover.
(12) Hallite joint. Front crankcase drain.
(13) ,, crankcase breather.
(14) ,, D.H.A.C. fuel pumps.
(15) ,, vacuum pump.
(16) ,, cover, airscrew governor facing.
(17) ,, oil tank vent connection.
(18) ,, Cover plate-timing gear cover drain.
(19) Fibre washer. thrust nut and valve casing.
(20) ,, small-main oil branch.
(21) Graphited Hallite washer between cylinder head and valve gear cover.
(22) Diaphragms of fuel pumps.

All oilways and oil pipes should be thoroughly cleared out, using compressed air if available. Oil all component parts of the engine freely and prime pipes and oilways during reassembly.

It should be noted that parts such as connecting rods, main bearing caps, the more important nuts and bolts, etc., are all marked with fitting numbers. These numbers should be strictly followed out and the engine reassembled with due consideration to such.

Reassembly of Camshaft and Tappets in Crankcase.—The camshaft should be replaced in the crankcase before fitting the tappets and guides, and the front and rear bearings bolted in position. This will prevent the tappets falling out while the tappets and guides are being fitted in the crankcase. Dermatine rings should be in place on the tappet guides before these are fitted to the crankcase. Care should be taken to see that the heel of the tappet sits squarely on the face of the cam, before the tappet guides are finally tightened in position. When the camshaft is assembled

in the crankcase, it should turn quite freely and the end float should be checked by inserting feeler gauges between the front and rear camshaft bearings and the faces of the shoulders on the camshaft.

Reassembly of Connecting Rods and Crankshaft.—Replace the oil seals in the crankshaft and retain by means of the central bolt, slotted nuts and split pins. When refitting the connecting rods to the crankshaft, the big end nuts should be pulled up dead tight, using the spanner (Part No. T.1900-1). The nuts should not be slacked back to insert split pins, and should the slot in the nut go beyond the hole in the bolt the nut should be faced off slightly to bring the next slot in line. The crankshaft gear and starter dog should then be bolted into rear end of crankshaft. Replace the half main bearings to crankcase and lower the crankshaft assembly into place. The shims must be fitted to the connecting rod bolts before assembly.

Reassembly of Main Bearings, Caps and Oil Gallery.—Fit the half main bearings to the caps, care being taken to see that they are fitted as numbered. The caps should then be fitted and the nuts pulled up dead tight using the ring spanner (Part No. T.800-51). The remarks on split pinning nuts (referred to in preceding para.) also applies in this case. Replace the oil gallery together with copper asbestos washers and retain by means of the cap nuts and locking wire.

The crankshaft at this stage should turn freely by hand.

Reassembly of Camshaft Idler Spindle.—Replace the thrust race to idler spindle and press on the front bush. Bolt the magneto driving gear to flange of camshaft idler gear, together with distance pieces, then press the idler gear into position on spindle. The rear bush may then be replaced. Replace the washer, nut and split pin. Refit the assembly to rear of crankcase and retain with the screw and lockwasher. Care must be taken when tightening the screw to see that the small locating pin is not sheared. The end float of the spindle should be adjusted if necessary, by means of shims (Part No. 1303-5) which should be placed between the thrust race and the front bush.

Reassembly of Pistons and Cylinder Barrels.—It should be noted that the pistons are now made to one weight only and carry the Part No. 2300-41/3 together with the fitting number stamped on the crown. The piston should be fitted on the connecting rod so that this fitting number comes to the same side as the camshaft. The scraper ring should be housed in the inner groove, *i.e.*, the groove farthest from the piston crown. It will be noted that part of the bearing face of this ring is machined away, and the ring must be fitted so that this machining is farthest from the piston crown. When refitting the circlips on the gudgeon pins, use circlip expander (Part No. T.1300-77A). Circlips, when fitted, must be tight in the grooves in the gudgeon pins; if at all slack, they must be renewed. A check should be made to see that the gudgeon pins are free to move in the piston and small end bores. Piston ring gaps should be spaced equally apart before fitting the pistons in the cylinders. When replacing the cylinders, use the piston ring clamp (Part No. T.1300-27B) to hold the piston rings in place. As the cylinder is pushed over the piston, the clamp will be pushed off and may be withdrawn before the cylinder is completely in place.

Reassembly of Cylinder Heads.—When assembling cylinder head use the valve spring compressor (Part No. T.1300-78A/1) and a block of

wood inside the head to hold the valves and springs in place while replacing the collets. Replace the rocker brackets complete with rockers. While the cylinder heads are being assembled, make sure that the cylinder baffle brackets and nuts are in place. The cylinder nuts should be screwed up sufficiently tight to hold the heads. The heads should then be lined up with a straight edge against the facing provided for this purpose directly below the port facings. The cylinder heads should then be tightened up at opposite corners, alternately. Finally the nuts should be screwed up firmly and evenly all round. It is important that the spanner (Part No. T.800-80) only be used for this operation, as using spanners of too great a leverage will result in a distorted cylinder head after warming up and running the engine. The hinge pieces to take the airscoop should then be bolted on to the cylinder head and underside of crankcase, and the small oil filter and its housing bolted to the front right-hand side of the crankcase.

Valve Timing.—Fit the two tappet rods to No. 1 cylinder and proceed with the valve timing as follows :—(Fig. 16.)

(1) Set the crankshaft so that the inlet closed position on the airscrew hub comes opposite the pointer fitted to the crankcase top cover.

(2) Set the tappets on No. 1 cylinder to 0·005 in. clearance.

(3) Set the camshaft so that the clearance is just taken up on the inlet closed position.

(4) Tap the camshaft gear into position selecting the most suitable keyway from the four provided. Before doing this the front camshaft bush should first be removed and the camshaft supported with a block of wood, this will prevent the possibility of damaging the camshaft bush when tapping on the gear. If the crankshaft gear or the camshaft gear has been changed, the timing will have to be reset, using the vernier keyways in the camshaft gear. It is possible, with this vernier, to get the timing within two or three degrees, in all positions. After temporarily fitting the front cover assembly, the engine should undergo an oil test under pressure, to ascertain that oil is reaching all parts, and the crankshaft turned to see that the connecting rod leak holes are clear. After test remove the front cover assembly.

Reassembly of Top Cover.—When replacing the crankcase top cover, care must be taken to see that the six fitted bolts are entered into their correct holes ; and approved jointing compound should be used on this and other metal to metal joints.

Reassembly of Crankshaft, Thrust Race, and Front Cover.—During the assembly of the thrust race the two spring steel washers must be fitted so that they present convex faces to the front and rear respectively of the thrust race.

When fitting the crankcase front cover, centralise this by means of a feeler gauge between the front cover and bronze cone before tightening up the nuts.

Reassembly of Oil Pump.—If a new spindle or bushes have been fitted to the oil pump, the specified endfloat will have to be obtained by facing off the bushes. The oil pump when assembled to the rear cover should turn quite freely by hand. Should any tightness be felt it must be rectified before fitting the rear cover to the engine.

Reassembly of Magneto Drive Shaft.—When reassembling the magneto drive shaft in the gear case, the following points should be observed :

(1) The housing for the ball race (Part No. 1303-24/1) and the oil retainer (Part No. 1303-25/1) must be fitted on the right-hand side.

(2) Ensure that the oil baffles (Part No. 1,303-21) are in place, and centralised, one on each side of magneto driving gear.

Reassembly of Rear Cover, Tachometer Drive, etc.—Lock the nut holding the oil pump driving gear to the spindle. When the rear cover is being fitted make sure that the oil pump gear is in mesh with the camshaft gear before the rear cover is pushed home.

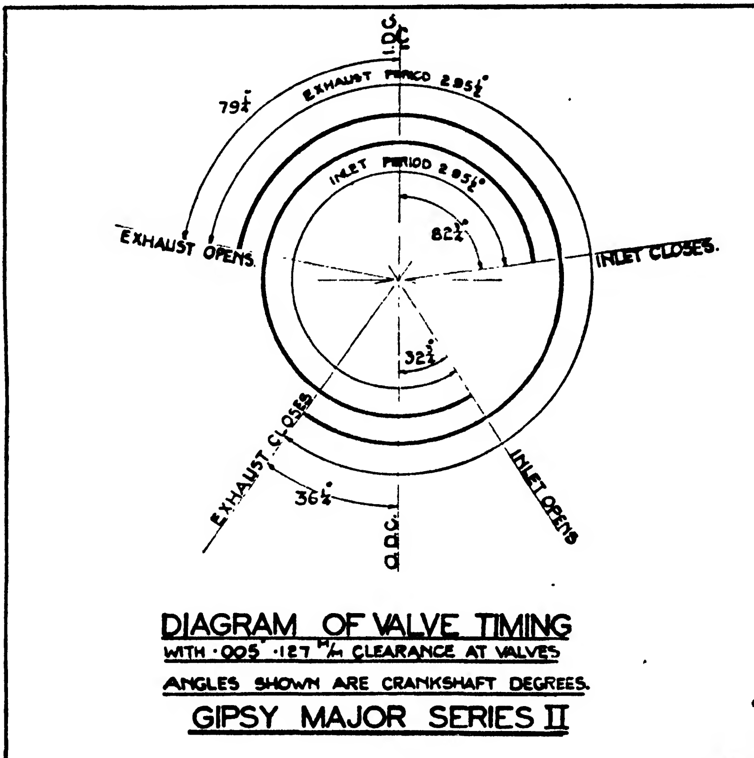


Fig. 16.

When reassembling the revolution indicator drive after a new spindle or bushes have been fitted, the necessary end float will have to be obtained by facing off the bushes. When replacing the revolution indicator drive gear box, ensure that the Dermatine ring is in place and that the pin holes are clear in the casing. The constant speed governor and vacuum pump assembly may then be bolted into position on the vertical faces provided, the vacuum pump on the left hand (port) side and constant speed governor on right-hand side. Replace the pressure oil filter, vertical suction filter and settling tank. The rear cover should undergo an oil test under pressure to ascertain that oil is reaching all parts, but before

doing this the banjo connection on the pressure filter casing should be blanked off.

Setting of Magneto Timing.—

(1) Set the contact breaker gap.

(2) Turn crankshaft to " Magneto Advance " mark on airscrew hub, ensuring that No. 1 cylinder is on firing stroke.

(3) Set magneto, with points about to break, in fully advanced position and distributor opposite No. 1 segment.

(4) Offer up magneto. Turn the rubber coupling round until both sets of teeth enter, one set in magneto coupling and the other set in the coupling in drive gear. When magnetos are finally tightened there should be a *slight* end-float on the rubber coupling.

(5) Synchronise magnetos at full advance with full throttle. No. 1 cylinder is wired to the front terminal of both magnetos. When engines are fitted with C.P. airscrews a timing tool (Part No. T.2100-3) will take the place of the above-mentioned airscrew hub, for timing.

NOTE.—When timing impulse magneto, ensure that impulse starter does not interfere with magneto timing.

Fitting of New Pistons and Connecting Rods.—If any new pistons or connecting rods have been fitted, the corresponding cylinders should be assembled in the crankcase before fitting the top cover so that the side clearance between the connecting rods and the piston bosses can be checked.

Fitting of New Throttle Spindle Bushes.—The old bushes must be pressed out of the carburettor body with a suitable stepped drift, and the replacement bushes similarly pressed into position. When they are correctly in place, they must be reamed right through with a 14 mm. expanding reamer, suitably adjusted to allow for wear of the throttle spindle. It is important that both bushes should be reamed to one setting to ensure alignment of the bores. Should adjustment be necesary to render the throttle valve central in the carburettor body, or endfloat adjusted, this must be effected by skimming the faces of the flanges of the bushes with a facing cutter.

Fitting of New Big End and Main Bearings.—As it is essential that the correct working clearance shall be present at the bearing, a check must be made by the paper strip method to ensure that the specified clearance has actually been provided. The paper strip should be the length of the bearing and approximately half an inch wide, and of the thickness of the specified minimum clearance, new. The strip should be placed in the centre of one half of the bearing. In the case of the connecting rods, the crankpin should be at the inner dead centre position. Movement of the journal in the bearing with this strip fitted should be comparatively easy ; if it is not, ease the bearing with a scraper as required. If the bearing is slack, insert a paper strip of a thickness equivalent to the maximum clearance, new ; with this the journal must be a tight fit in the bearing, otherwise the clearance will be beyond the permissible limit.

Fitting of New Rocker Pads.—Remove the old pad by filing off the peening which holds the pad into the rocker, and, taking care to be central, drill a 5 mm. hole down the length of the stem of the pad, almost to the pad itself. Knock out the pad with a stepped drift which is a clearance fit in the 5 mm. hole, taking care to employ the minimum weight and number

of hammer blows. Offer the new pad into position making sure that it fits snugly with the small keep on the rocker. Rest the pad on a block of hard brass and peen over the top of the stem until flush with the surface of the rocker.

Dismantling and Reassembly D.H.A.C. Petrol Pump.—Dismantling is a straightforward operation, but care should be taken to avoid mixing up parts of various pumps when in the dismantled condition.

The following points should be watched during reassembly :—When tightening nut on diaphragm pull rod, enter the six screws through diaphragm into body, this will hold diaphragm in correct position and facilitate final entry of screws.

Do not tighten this nut down too tightly, as it should only be sufficiently tight to avoid leakage of fuel through the centre of diaphragm.

When fitting valves and valve caps, make sure that the valve is in guide in the cap before tightening cap down.

Before tightening the six screws holding top cover, push diaphragm pull-rod up until the edge of large washer (B) is against lower edge of valve seat and keep in this position until screws are finally tightened.

Should rocker arm (D), rocker links, or pull rod (F) have been renewed, the pump will have to be checked as follows :—The completely assembled pump should be fitted on a test rig, or an engine. The camshaft should be turned until the eccentric (H) is in position of full lift. A further movement (measured between the striking pad of lever (D) and eccentric (H) of 0·035 in. to 0·045 in.) should then be obtained. To obtain this it may be necessary to fit a washer of different thickness between the small disc (B) and the shoulder on the pull rod (F.)

The diaphragm spring (C) is somewhat similar in appearance to the rocker arm spring (S). To avoid mistakes in reassembly, the diaphragm spring (C) is painted blue, and care must be taken that these springs are fitted in their correct positions.

Magnetos, Carburettor, Electric Starter.—Magnetos, carburettor and electric starter and any special equipment should be overhauled before being refitted to the engine, reference being made to manufacturers' manuals.

Running in and Testing of Engine.—When assembly is complete the engine should, if possible, be run on a special stand and driven by external means. If this equipment is not available, engine should be run in at 800 to 900 R.P.M. for one hour, before being subjected to the regulation endurance test on an approved test bed. After the endurance, power and consumption test, the engine should be stripped sufficiently for the examination of new parts which have been fitted, after which it should be reassembled and subjected to a final proof run.

SCHEDULE OF FITS, CLEARANCES AND REPAIR TOLERANCES
NOTES ON APPLICATION OF SCHEDULE

The data regarding fits and clearances are specified under four headings, *i.e.* " Dimensions, New," " Permissible Worn Dimensions," " Clearances, New," and " Permissible Worn Clearances."

All dimensions are given in millimetres and decimals of a millimetre except where otherwise stated.

The figures in the column " Dimensions, New," are the drawing sizes to which parts are made. These dimensions are given in limit form and represent the minimum and maximum size to which parts may be accepted when new, as for example $\frac{13{\cdot}968}{13{\cdot}981}$ for tappet diameter.

The difference between the minimum and maximum dimensions quoted in para. 3 is known

as the manufacturing tolerance. This tolerance is necessary as an aid to manufacturers, and its numerical value is an expression of the accuracy required by the design ; it may also be considered as a numerical expression of the desired quality of workmanship. For the tappet example referred to in para. 3 the tolerance is 00·13.

The dimensions in the column " Permissible Worn Dimensions " represent the limits of size to which parts may be worn and refitted for a further period of service.

Note.—These dimensions have been so fixed that the components are fit for the full period of further service which is normally permitted between complete overhauls. When, however, parts are found during complete overhaul to be worn beyond the limits laid down, they must be discarded as unserviceable.

In the column " Clearance, New," is given the minimum and maximum working clearance obtainable with new parts when assembled together, and is a function of the minimum and maximum sizes of mating parts in the " Dimensions, New " column. For example, if a new tappet made to the minimum size is 13·968 is assembled with a new tappet guide having a bore to the maximum size 14·007 the resulting working clearance will be 0·039, similarly, if a new tappet to the maximum size 13·981 is assembled with a new tappet guide to the minimum size 13·993, the resulting working clearance will be 0·012.

The " Permissible Worn Clearance " is the limit of working clearance permissible between any two parts assembled together.

If a male member, worn to the minimum size, is assembled with a corresponding new female part, machined to the minimum drawing limit, the resulting working clearance between the two parts will in most instances correspond with the maximum permissible worn clearance. Similarly if a female part, worn to the maximum permissible size, is assembled with a corresponding male part, machined to the maximum drawing limit, the resulting working clearance will be the same.

Considering the tappets and guides as an example :—

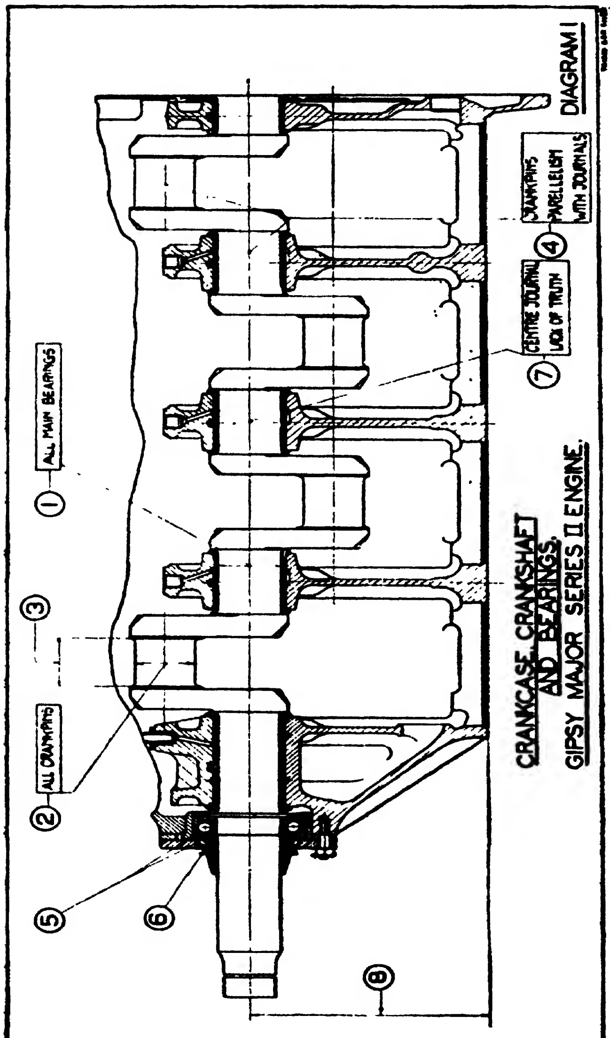
New tappet guide having bore to minimum drawing limit	13·993
Tappet worn to permissible size	13·897
Resulting Clearance	0·114
Tappet guide worn to permissible size	14·095
New tappet to maximum drawing limit	13·981
Resulting Clearance	0·114

CRANKCASE, CRANKSHAFT AND BEARINGS (Diagram No. 1)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	JOURNALS AND BEARINGS STANDARD SIZE					
	Journal Dia.	51·968 / 51·987	51·417	0·063 / 0·088	0·127	Minimum Worn Size. Unless new bearings are required, bearings which are found to be within the limit of wear before being refitted, are to be carefully inspected to ensure that the white metal is in a serviceable condition. Permissible Worn journal sizes shown gives a wear tolerance of 0·051 after 4th stage of regrind.
	Bearings Bore	52·050 / 52·056 (Finished Size)	52·114			
	Journals Stages of regrinding					
	1st	51·845 / 51·862	..	..	..	When regrinding care is to be taken to see that no material is removed from the face of the crankwebs.
	2nd	51·718 / 51·737	..	..	..	
	3rd	51·593 / 51·612	..	..	..	
	4th	51·468 / 51·487	..	..	..	
	Journal Ovality		0·05			
	JOURNALS BEARINGS. STAGES OF UNDERSIZE					
	1st	51·925 / 51·931	..	..	..	
	2nd	51·800 / 51·806	..	..	..	
	3rd	51·675 / 51·681	..	..	..	
	4th	51·550 / 51·556	..	..	..	
(2)	CRANKPINS. STANDARD SIZE					
	Crankpin Dia.	49·968 / 49·987	49·898 (See Remarks)	0·038 / 0·063	0·127	Minimum Worn Size.
	Crankpins Stages of regrinding					
	1st	49·843 / 49·862	..	..	..	When regrinding care is to be taken to see that no material is removed from the face of the crankwebs.
	2nd	49·718 / 49·737	..	..	..	
	3rd	49·593 / 49·612	..	..	..	

Crankcase, Crankshaft and Bearings (Diagram No. 1)—*Continued*

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
	Crankpins Stages of regrinding 4th	49·468 / 49·487	..	..	..	
	Crankpins ovality		0·05	..	.	
(3)	CRANKPINS LENGTH	50·988 / 51·012	51·142	..	..	
(4)	CRANKPINS, PARALLELISM Lack of parallelism of crankpin with journals per inch of length.		0·040	..	..	Measured in two planes at 90°.
(5)	CRANKSHAFT END FLOAT Crankshaft ball bearings end float between inner and outer races			0·002" / 0·003"		
(6)	CRANKSHAFT FRONT COVER Rear Cone (Dia. on Swirl)	71·424 / 71·462	71·364	0·198 / 0·276	0·296	
	Front Cover Bore	71·660 / 71·700	71·758			
(7)	CRANKSHAFT CENTRE JOURNAL, LACK OF TRUTH Lack of truth of centre journal when crankshaft is supported by journals one and five in " V " blocks (Errors due to ovality to be subtracted)		0·05			Dial indicator reading 0·100 = 0·004"
(8)	WEAR ON FACE OF CRANKCASE CAUSED BY FRETTING OF CYLINDER BARRELS		0·250 (See Remarks)			When this figure is exceeded the crankcase face is to be machined down in accordance with Drawing M.R. 2101-1 Sheet 1, and a packing shim representing the thickness of metal removed is to be fitted under the cylinder barrel flanges. Four stages of refacing are allowed, details of which are given on this drawing together with details of the appropriate shims. The maximum amount of metal which may be removed is 1·250 which represents a dimension of 192·700 / 192·850 between the top and bottom faces of the crankcase. When this stage is reached the face may be allowed to wear down 0·25, after which the crankcase is to be discarded.



1 ALL MAIN BEARINGS
2 ALL CRANKPINS
3
4 CRANKPINS PARALLELISM WITH JOURNALS
5
6
7 CENTRE JOURNAL LACK OF TRUTH
8
DIAGRAM I
CRANKCASE, CRANKSHAFT AND BEARINGS.
GIPSY MAJOR SERIES II ENGINE.

Fig. 17.

PISTONS AND CONNECTING RODS (Diagram No. 2)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	CONNECTING RODS, ERRORS OF ALIGNMENT					
	Errors of alignment Big and Small ends. Per inch of mandrel:					
	Parallelism	..	0·051	..	..	
	Twist	..	0·076	..	..	
(2)	BIG END BEARINGS					
	Bore. Standard size	50·025 / 50·031	50·114	..	..	
	STAGES OF UNDERSIZE					
	Bore 1st	49·900 / 49·906	..	..	..	
	2nd	49·775 / 49·781	.	..	..	
	3rd	49·650 / 49·656	..	..	..	
	4th	49·525 / 49·531	..	..	..	
(2)	BIG END BEARINGS					
	Working Clearance for Big End Bearings on Crankpins	..	..	0·038 / 0·063	0·127	Unless new bearings are required, bearings which are found to be within the limits of wear are to be carefully inspected to ensure that the white metal is in a serviceable condition before being refitted.
(3)	BIG END BEARINGS END FLOAT					
	Big End Bearings, Width	50·862 / 50·888	50·734	..	..	
	End Float of Big End Bearings on crankpins	..	..	0·100 / 0·150	0·254	To obtain increased nip on connecting rod bearings $0{\cdot}0045''\frac{+0{\cdot}000\frac{1}{4}''}{-0{\cdot}000''}$ may be taken off both sides of cap, and connecting rod tightened to take up this clearance. Reference must be made to Drawing S.K.8593/2, sheet 3.
(4)	GUDGEON PINS IN CONNECTING RODS					
	Small end, bore	25·000 / 25·020	25·070	0·006 / 0·039	0·076	
	Gudgeon Pin, Dia in centre	24·981 / 24·994	24·924			
	Gudgeon Pin, Ovality	..	0·025	..	..	Minimum dia. to be such that "permissible Worn Clearance" for gudgeon pin is not exceeded

Pistons and Connecting Rods (Diagram No. 2)—*Continued*

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(5)	GUDGEON PIN IN PISTON					
	Gudgeon Pin Boss, Bore	24·993 / 25·013	25·062	0.001 Tight / 0·032 Slack	0·068	
	Gudgeon Pin, dia. at ends	24·981 / 24·994	24·925			
	End Float	..	..	0·0355" / 0·059"	0·068"	
(6)	COMPRESSION RINGS IN RING GROOVES					
	Compression Ring Groove Width Inner	2·134 / 2·146	2·274	0·115 / 0·152	0·255	
	Compression Ring Width-Inner	1·994 / 2·019	1·879			
	Compression Ring Grooves Width Outer	2·134 / 2·146	2·274	0·115 / 0·152	0·255	
	Compression Ring Width-Outer	1·994 / 2·019	1·879			
(7)	SCRAPER RINGS IN RING GROOVES					
	Scraper Ring Groove Width	2·625 / 2·650	2·730	0·125 / 0·162	0·230	
	Scraper Ring, Width	2·488 / 2·500	2·395			
(8)	COMPRESSION RING GAP					
	Measured when piston is at small end of cylinder, *i.e.* nearest combustion chamber	..	..	0·012" / 0·020	0·055"	
(9)	SCRAPER RING GAP					
	Measured when piston is at small end of cylinder, *i,e,* nearest combustion chamber	..	..	0·005" / 0·011"	0·044"	
(10)	PISTONS, LAND AND SKIRT DIAMETERS AND CLEARANCE IN CYLINDER					
	Dia. of Skirt:					
	Top (Adjacent to scraper ring)	117·140 / 117·190	117·070 (See remarks)	0·565 / 0·665	0·905	Measured in large end of cylinder, *i.e.* farthest from combustion chamber.
	Bottom	117·335 / 117·385	117·125 (See remarks)	0·370 / 0·470	0·850	
	Dia. of crown of piston	116·927 / 116·953	..	..	..	

Pistons and Connecting Rods (Diagram No. 2)—*Continued*

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
	Clearance between Piston and Cylinder when measured at small end cylinder, *i.e.* nearest combustion chamber					
	Top Land	..	..	0·597 0·673	0·597 0·973	
	2nd Land	..	..	0·597 0·673	0·597 0·973	
	3rd Land (Near Piston Crown)			0·802 0·878	0·802 1·528	
(11)	PISTONS AND CONNECTING RODS ASSEMBLY. WEIGHT VARIATION Permissible variation in Weight between any two connecting rods, complete with gudgeon pins and pistons and all details, in any individual engine 1 oz.—10 drms.	..	..	..	..	

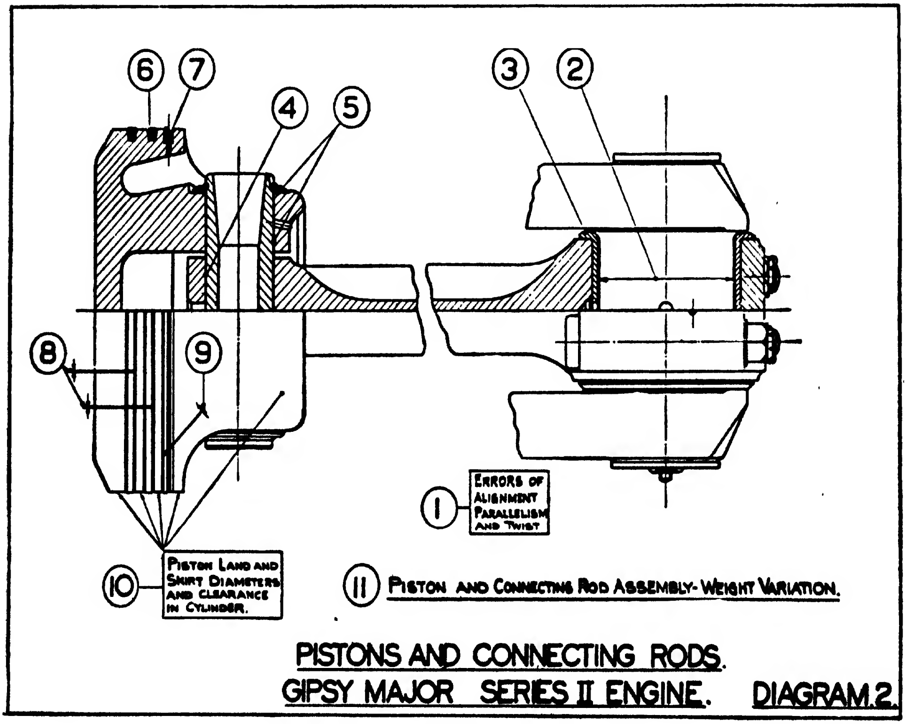
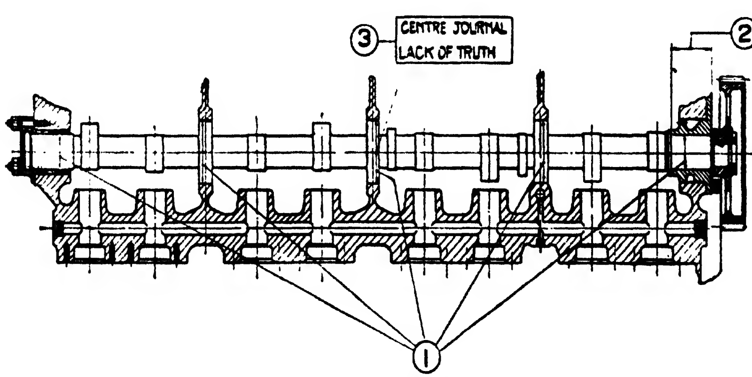


Fig. 18.

CAMSHAFTS AND BEARINGS (Diagram No. 3)

Diag. Ref. No.	Parts and Descriptions	Dimensions New	Permissible Worn Dimension	Clearance New	Permissible Worn Clearance	Remarks
(1)	**CAMSHAFT IN BEARINGS**					
	Bearings, Front and Rear Bore	27.993 / 28·019	28·158	0·025 / 0·083	0·190	Crankcase repair operation to fit camshaft bushes. Drawing M.R. 2101-1 Sheet 2.
	Journals, Front and Rear, dia.	27·936 / 27·968	27·803			
	Bearings intermediate, bore	50·972 / 50·985	51·112	0·025 / 0·063	0·165	
	Journals, intermediate, dia.	50·922 / 50·947	50·807			
(2)	**CAMSHAFT END FLOAT**					
	Camshaft, width between flange on camshaft and face of timing gear	38·050 / 38·100	38·203	0·025 / 0·125	0·178	
	Rear End Bush, Width	37·975 / 38·025	37·872			
(3)	**CAMSHAFT CENTRE JOURNAL, LACK OF TRUTH**					
	Lack of truth of centre journal when front and and rear Journals are supported on "V" Blocks.	..	0·050	..	..	Dial indicator reading 0·100 = 0·004"



CAMSHAFT AND BEARINGS.

GIPSY MAJOR SERIES II.

DIAGRAM 3

Fig. 19.

TAPPETS AND GUIDES (Diagram No. 4)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	TAPPETS, CYLINDRICAL PORTION IN GUIDES					
	Guide Bore	13·993 / 14·007	14·095	0·012 / 0·039	0·114	
	Tappet Diameter	13·968 / 13·981	13·879			
(2)	TAPPETS, RECTANGULAR PORTION IN GUIDES					
	Guide Slot, Width	13·993 / 14·020	14·133	0·012 / 0·052	0·152	
	Tappet, Flat, Width	13·968 / 13·981	13·841			

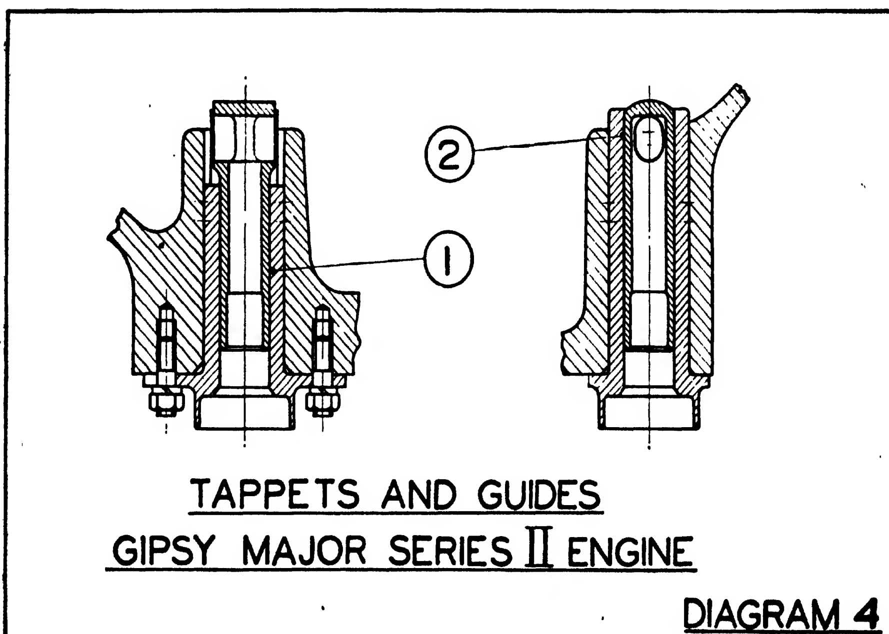


Fig. 20.

CYLINDERS, VALVES AND ROCKER GEAR (Diagram No. 5)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	CYLINDER BORE					
	Measured at small end of cylinder	117·755 / 117·805	117·955	..	..	Local wear at top of cylinder bore may be permitted up to 0·200 above the max.; new Dimension, *i.e.* 117·805 + 0·200 = 118·005
	Measured at large end of cylinder	117·975 / 118·025	118·175	..	..	
	Ovality, measured at small end of cylinder, *i.e.* nearest to the cylinder head	..	0·076	..	..	
	Ovality, measured at large end of cylinder, *i.e.* farthest from cylinder head	..	0·076	..	..	
	Stage of regrind :					
	Measured at small end of cylinder	117·955 / 118·005	..	..	..	
	Measured at large end of cylinder	118·175 / 118·225	..	..	..	
(2)	VALVES IN GUIDES. VALVE GUIDE, INLET					
	Bore measured 12 mm. from either end	11·050 / 11·070	11·170	0·080 / 0·120	0·200	
	Valve inlet, stem dia.	10·950 / 10·970	10·850			
	VALVE GUIDE, EXHAUST					
	Bore measured 12 mm. from either end	11·050 / 11·070	11·170	0·080 / 0·120	0·200	
	Valve, Exhaust Stem dia.	10·950 / 10·970	10·850			
(3)	VALVE INLET AND EXHAUST Ovality of Stems	..	0·076	..	..	Minimum Diameter to be within "Permissible Worn Dimensions" for valve stems
(4)	VALVE GUIDE BORES. OVALITY. VALVE GUIDES, INLET AND EXHAUST OVALITY OF BORE					
	Bore measured 12 mm. from either end	..	0·076	..	..	Minimum Diameter to be within "Permissible Worn Dimensions" for valve guides.

Cylinders, Valves and Rocker Gear (Diagram No. 5)—*Continued*

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(5)	VALVE SPRINGS INLET AND EXHAUST OUTER SPRINGS:					
	Test Length	1·579"	..	..	..	
	Equivalent Load	56·1 lbs. ——— 58·6 lbs.	53·75 lbs.	..	..	
	INNER SPRINGS:					
	Test Length	1·579"	..			
	Equivalent Load	38·1 lbs. ——— 40·1 lbs.	36·85 lbs.	.. ..	.. ..	
(6)	VALVE SEATS IN CYLINDER HEAD DIA. OF 30° SEATINGS:					
	Inlet	50·450 ——— 50·550	52·00	..	..	Should valve seats require replacing see Drawing M.R. 2302-5 Sheets 3 and 4, Cylinder Head, 1st and 2nd replacement, valve seats.
	Exhaust	47·950 ——— 48·050	49·5	..	...	
(7)	VALVES, REGRINDING Valves, minimum thickness of valve after regrinding of valve face (*i.e.* Dimension from lower edge of valve face to bottom of valve head)					
	Inlet Valve	1·5	0·750	..	..	
	Exhaust Valve	3·26	2·780	..	..	
(8)	VALVE ROCKER BUSHES ON SPINDLE					
	Bushes, Bore	13·993 ——— 14·007	14·095	0·012 ——— 0·039	0·114	
	Spindle, Dia.	13·968 ——— 13·981	13·879			
(9)	VALVE ROCKER End Float	..	..	0·007" ——— 0·016"	..	
(10)	VALVE ROCKER PAD Thickness of Head	3·5	3·1	..	.	Valve rocker pad may be reconditioned within the limits stated by hand stoning Contact Face. Care must be taken to keep the face true with longitudinal axis of pad.
(11)	VALVE GUIDES IN CYLINDER HEAD	..	..	..	..	Should guides become loose in cylinder head, the head may be bored out to Drawing M.R. 2302-5 Sheet 1 and 2 Cylinder Head, 1st and 2nd replacement, valve guides.

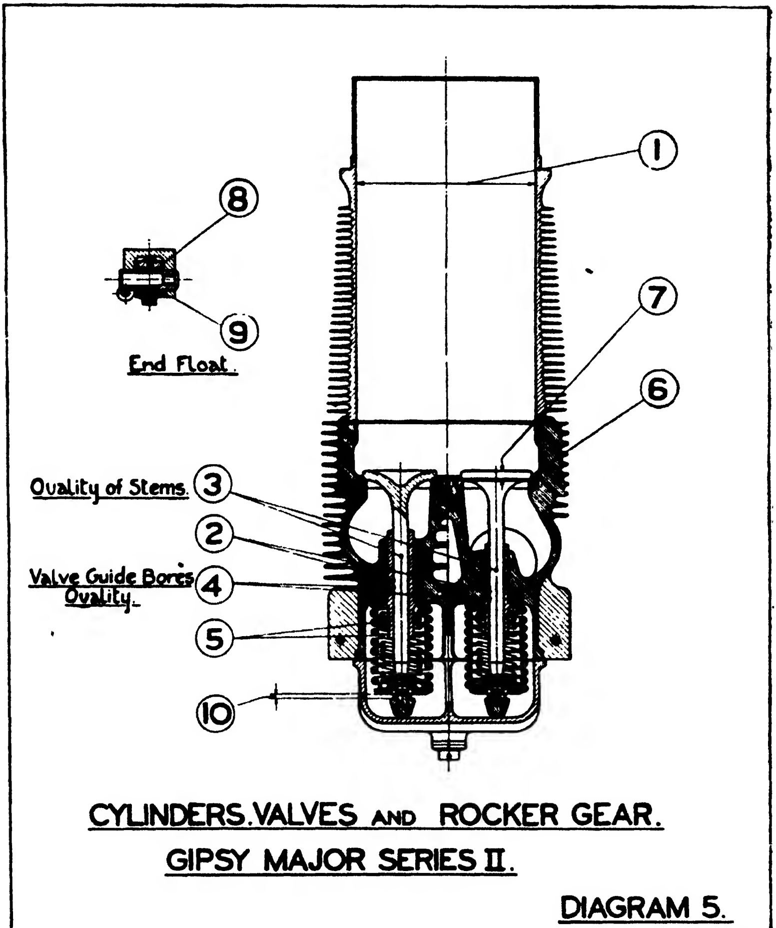

1
8
9
End Float.
7
6
Quality of Stems.
3
2
Valve Guide Bores Quality.
4
5
10
CYLINDERS. VALVES AND ROCKER GEAR.
GIPSY MAJOR SERIES II.
DIAGRAM 5.

Fig. 21.

MAGNETO DRIVEN GEAR (Diagram No. 6)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	MAGNETO DRIVEN GEAR ASSEMBLED ON CROSS SHAFT					
	End Float	..	..	0·003″ / 0·008″	0·011″	
(2)	Blacklash	..	..	0·005″ / 0·010″	0·015″	

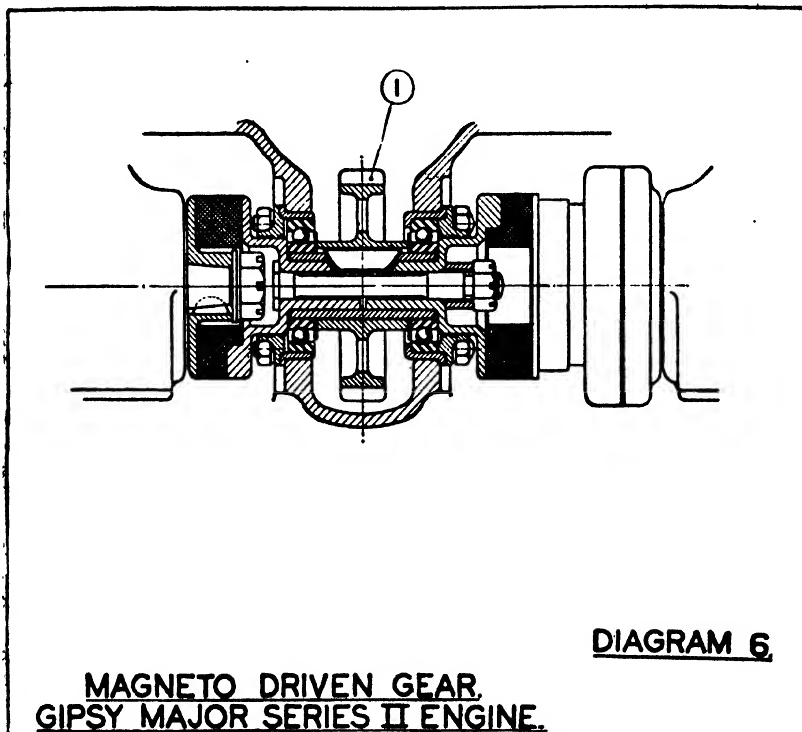


Fig. 22.

TIMING GEARS (Diagram No. 7)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	IDLER GEAR, ASSEMBLED WITH BUSHES ON SPINDLE					
	Bushes Bore	17·993 / 18·013	18·068	0·065 / 0·098	0·140	
	Spindle Dia.	17·915 / 17·928	17·853			
(2)	End Float	..	..	0·002″ / 0·004″	0·015″	Adjustable by shim between thrust race and shoulder of bearing bush. Shims are supplied in the following range of thickness 0·002″, 0·005″, 0·010″.
(3)	TIMING GEARS (SPUR) Backlash between any pair	..	.	0·0055″ / 0·007″	..	

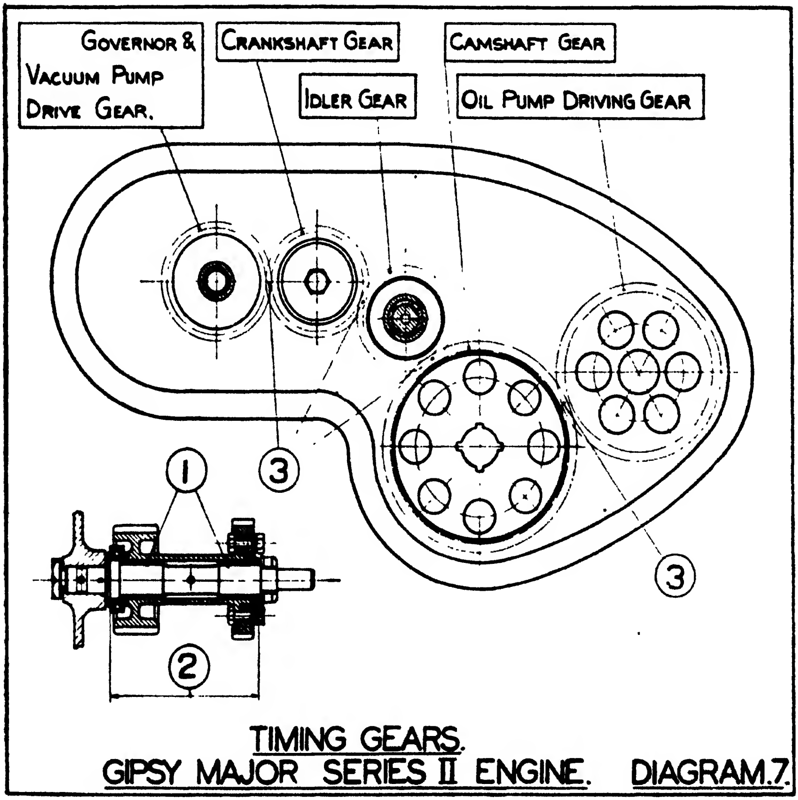
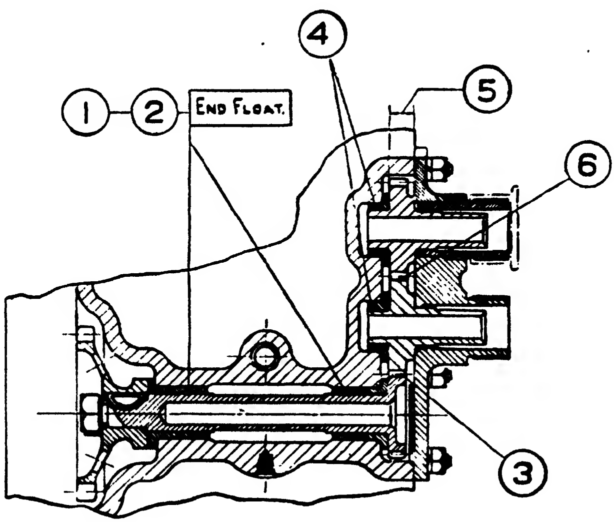


Fig. 23.

TACHOMETER DRIVES (Diagram No. 8)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	DRIVEN GEAR TACHOMETER SHAFT					
	Bushes Bore	11·993 / 12·007	12.070	0·025 / 0·062	0·102	
	Spindle, Dia.	11·945 / 11·968	11·891			
	Width over bushes	74·850 / 74·890	74·721	0·110 / 0·187	0·279	
	Spindle length	75·000 / 75·037	75·169			
(2)	End Float	..	..	0·0043″ / 0·0073″	0·011″	
(3)	Gear Backlash	..	.	0·0035″ / 0·0075″	0·010″	
(4)	DRIVEN AND DRIVING GEAR IN BEARINGS					
	Bearing, bore	11·993 / 12·007	12·070	0·025 / 0·062	0·102	
	Spindle, Dia.	11·945 / 11·968	11·891			
	Housing Width	8·050 / 8·125	8·275	0·075 / 0·200	0·300	
	Gears width	7·925 / 7·975	7·750			
(5)	End Float	..	..	0·003″ / 0·008″	0·012″	
(6)	Backlash	..	..	0·004″ / 0·006″	0·010″	



TACHOMETER DRIVES

GIPSY MAJOR SERIES II ENGINE. DIAGRAM 8

Fig. 24.

OIL PUMP (Diagram No. 9)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	**Pump Bearings**					
	Bushes Bore	15·995 / 16·013	16·089	0.018 / 0·064	0·114	
	Journal, Dia.	15·949 / 15·975	15·879			
(2)	**Pump Gears**					
	Backlash	..	..	0·008″ / 0·012″	0·016″	
(3)	**Oil Pump Driving Gear**					
	End Float	..	..	0·038 / 0·109	0·178	
	Backlash	..	..	0·002″ / 0·006″	0·008″	
(4)	**Pump Gears in Casing**					
	Pump casing with bushes fitted Width between flanges	25·050 / 25·124	25·153	0·075 / 0·174	0·178	
	Pump Gear. Length	24·950 / 24·975	24·872			
(5)	**Pump Gears Clearance on Diameter**					
	Pump Casing, Bore	35·493 / 35·545	35·595	0·098 / 0·175	0·200	
	Pump Gears dia. over teeth	35·370 / 35·395	35·293			

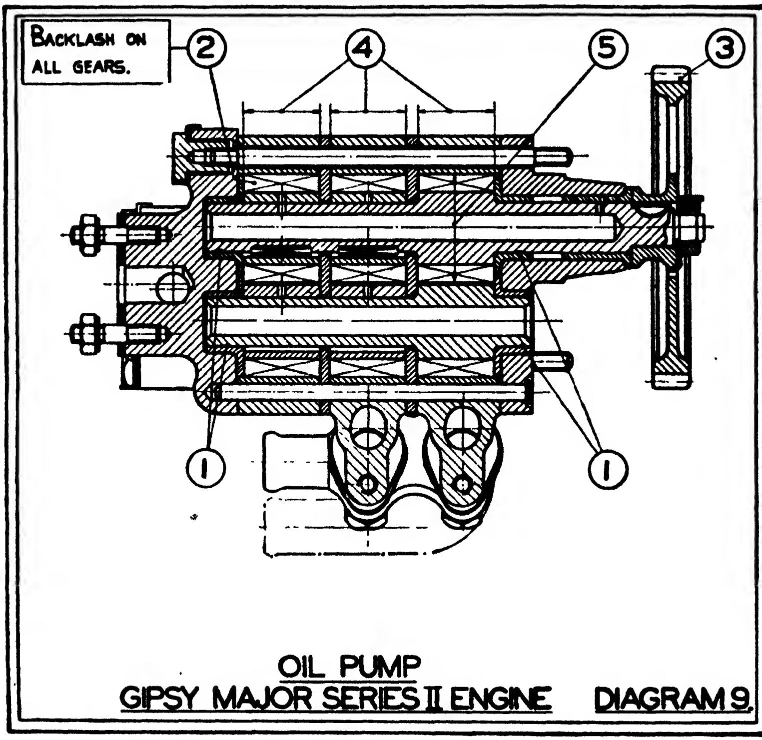

BACKLASH ON
ALL GEARS.
2
4
5
3
1
1
OIL PUMP
GIPSY MAJOR SERIES II ENGINE DIAGRAM 9.

Fig. 25.

VACUUM PUMP AND AIRSCREW GOVERNOR DRIVE (Diagram No. 10)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn C.earance*	*Remarks*
(1)	MAIN DRIVE SHAFT HOUSING					
	Bushes Bore	17·993 / 18·013	18·089	0·018 / 0·064	0·114	
	Drive Shaft, Dia.	17·949 / 17·975	17·879			
	Width over Bushes	36·950 / 36·975	36·850	0·075 / 0·125	0·200	
	Spindle Length	37·050 / 37·075	37·175			
	End Float	..	..	0·003" / 0·005"	0·008"	
(2)	Backlash Spur Gear	..	..	0·003" / 0·007"	0·010"	
(3)	Backlash Bevel Pinion	..	..	0·003" / 0·008"	0·012"	
(4)	AIRSCREW GOVERNOR DRIVE					
	Housing Bore	27·993 / 28·019	28·158	0·025 / 0·083	0·190	
	Bevel Pinion Spindle, Dia.	27·936 / 27·968	27·803			
	Housing Width	31·950 / 31·975	31·850	0·075 / 0·125	0·200	
	Spindle Length	32·050 / 32·075	32·175			
	End Float	..	..	0·003" / 0·005"	0·008"	
(5)	Backlash Bevel Pinion	..	..	0·003" / 0·008"	0·012"	

Vacuum Pump and Airscrew Governor Drive (Diagram No. 10)—*Continued*

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(6)	VACUUM PUMP DRIVE					
	Housing Bore	22·993 / 23·013	23·089	0·018 / 0·064	0·114	
	Bevel Pinion, Spindle Diameter	22·949 / 22·975	22·879			
	Housing, Width	21·950 / 21·975	21·850	0·075 / 0·125	0·200	
	Spindle Length	21·050 / 22·075	22·175			
	End Float	..	..	0·003″ / 0·005″	0·008″	
(7)	Backlash, Bevel Pinion	..	..	0·003″ / 0·008″	0·012″	

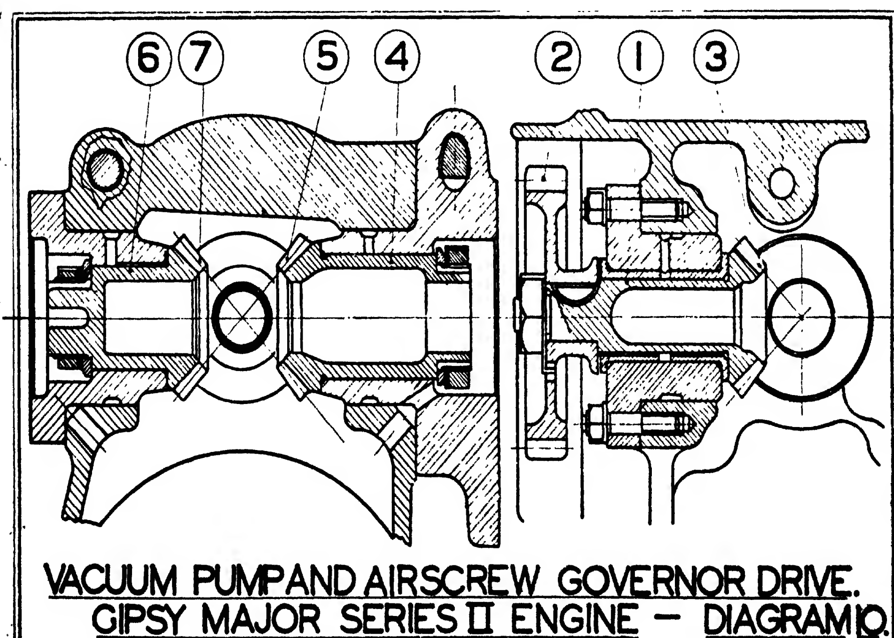


Fig. 26.

D.H. A.C. PETROL PUMP (Diagram No. 11)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	Rocker Arm Pin in Lever					
	Pin, Dia.	0·2445″ / 0·245″	0·2405″	0·0005″ / 0·0030″	0 005″ (See remarks)	Permissible Worn Clearance of 0·005″ applies only to that portion of the pin on which rocker lever and links have their bearings.
	Lever, Bore	0·2455″ / 0·2475″	0·250″			
(2)	Rocker Arm Pin in Link					
	Link, Bore	0·2455″ / 0·2475″				
(3)	Rocker Arm Pin in Body					
	Body, Bore	0·2435″ / 0·2445″	..	(See remarks)	Rocker arm pin in body on diameter.	Max. + 0·0015″ above size of hole. Min. Equal to size of hole.
(4)	Link Pins in Links					
	Link, Bore	0·184″ / 0·186″	0·1885″	0·0020″ / 0·0045″	0·0065″	
	Link, Pin Dia.	0·1815″ / 0·1820″	0·1775″			
(5)	Link Pin in Pull Rod					
	Pull Rod, Bore	0·1825″ / 0·1845″	0·1870″	0·0005″ / 0·0030″	0·005″	
	Link, Pin Dia.	0·1815″ / 0·1820″	0·1775″			
(6)	Pull Rod in Gland					
	Gland, Bore	0·380″ / 0·382″	0·386″	0·005″ / 0·009″	0·011″	
	Pull Rod, Dia.	0·373″ / 0·375″	0·369″			
(7)	Priming Lever in Bottom Cover and Cap					
	Bottom cover and cap, Bore	7·993 / 8·007	8·132	0·493 / 0·507	0·632	
	Priming Lever, Dia.	7·5 / 7·5	7·361			

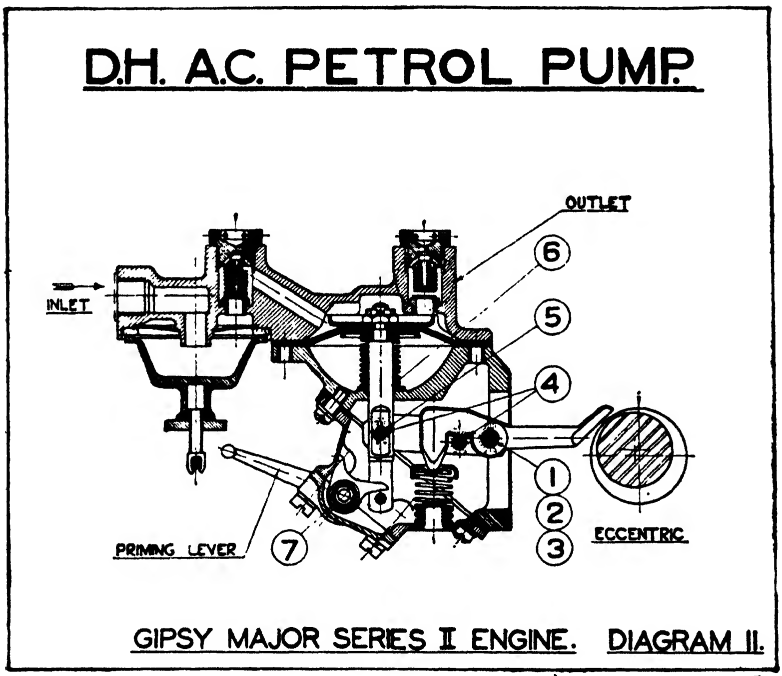

D.H. A.C. PETROL PUMP.
OUTLET
INLET
6
5
4
1
2
3
7
PRIMING LEVER
ECCENTRIC
GIPSY MAJOR SERIES II ENGINE. DIAGRAM II.

Fig. 27.

CARBURETTOR (Diagram No. 12)

Diag. Ref. No.	*Parts and Descriptions*	*Dimensions New*	*Permissible Worn Dimension*	*Clearance New*	*Permissible Worn Clearance*	*Remarks*
(1)	THROTTLE SPINDLE					
	Bush Bore	0·3755" / 0·3765"	0·379"	0·0005" / 0·002"	0·004"	Bushes—hand reamed, if necessary, when assembled in carburettor body to give minimum clearance of 0·0005".
	Spindle	0·3745" / 0·375"	0·3715"			

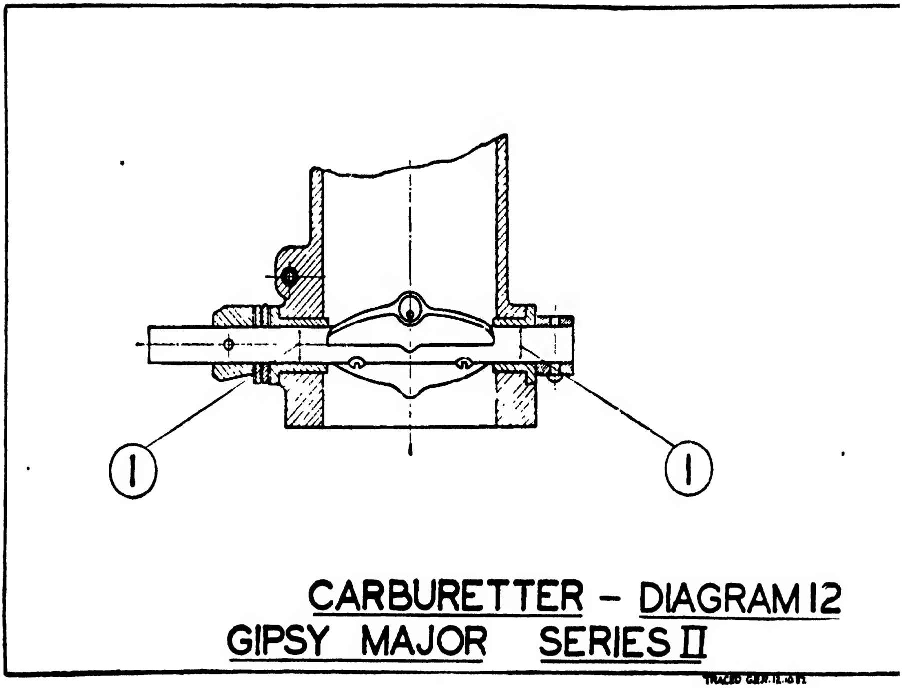


Fig. 28.

ROUTINE MAINTENANCE AND OVERHAUL SCHEDULE

Recommended Maintenance Schedule

The Gipsy Major Series II Aero Engine will normally be inspected and maintained by licensed ground engineers and their training will indicate the nature of the inspection routine and work to ensure reliable and care-free operation, but, for the guidance of all concerned, the following covers broadly the points to be observed.

Daily Inspection in Preparation for Flight

(i) Attention to pilot's previous reports, if any.
(ii) Check all controls for free movement and normal operation.
(iii) Inspect engines and installation to ensure no slacking, displacement, chafing or leaks.
(iv) Rotate spindle in Auto-Klean filters.
(v) Check fuel pumps independently by operating priming levers.
(vi) Run up engines.
(vii) Verify engine cowling properly fastened.

After 25 Hours Flying

(i) Routine as Daily Schedule, including the following:—
(ii) Remove sparking plugs, dismantle, clean, re-assemble and pressure test.
(iii) Check valve clearances and reset if necessary.
(iv) Clean suction oil filters.
(v) Clean petrol filters.
(vi) Remove and check carburettor jets and flush through float chamber, including pipe lines between pumps and carburettor.
(vii) Check contact breaker gap, reset if necessary and clean distributors.
(viii) Drain oil system, including valve gear covers, replenish with new oil.
(ix) Check tightness of airscrew bolts. This should be done more frequently if airscrew of wooden construction is new and if the aircraft is operating in a hot climate.
(x) Lubricate all working parts of controls.

After 250 Hours Flying

The Auto-Klean pressure filter should be dismantled from its casing and cleaned, including the casing.

After 600 Hours Flying

The engine should be taken from the airframe and given a complete overhaul.

IN-LINE

PART 2.—NAPIER—"DAGGER"

By the Technical Publications Dept.,
D. NAPIER & SON, LTD.

INTRODUCTION.

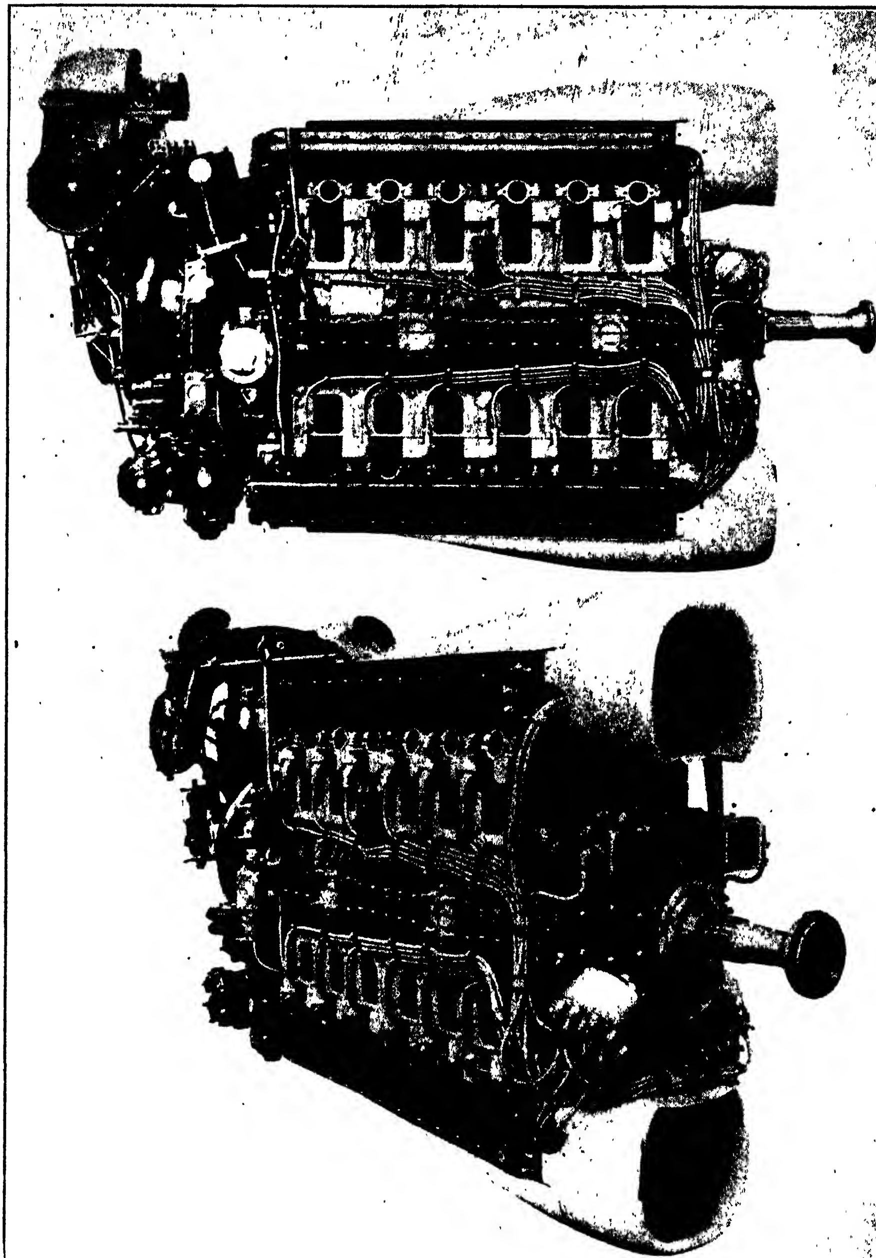
The Napier-Halford Dagger Series III. (Fig. 1) engine represents a new departure in aero engine practice as it will be observed that the cylinders are disposed in four banks of six cylinders, in "H" formation, and that two separate crankshafts are used. This engine, and its more powerful successor the Series VIII., are the logical outcome of many years of development on the smaller but similar 16 cylinder Rapier, and the type was inaugurated to fill the need for a powerful engine combined with small frontal area. The use of a large number of small cylinders with high compressions and higher crankshaft speeds, than are permissible with the conventional type of aero engine, has enabled these objects to be gained with the added benefits of increased economy and smoother running. The development of an improved type of cowling has enabled surprisingly low cooling drag figures to be obtained.

In the preparation of the following section on the Dagger Series III. engine, endeavour has been made to present as much of the essential information as possible concerning the general construction, running, maintenance and top overhaul of the engine. It has not been possible within the scope of a publication of reasonable size to enter fully into matters appertaining to complete overhaul as this is a subject of very considerable extent in itself. But it is hoped that the information given will be sufficiently comprehensive to enable readers, particularly those directly concerned with the running and maintenance of aero engines, to gain an adequate grounding in the principles of maintenance and operation of the above type.

It should be noted that standard procedure has been complied with throughout, particularly on questions of maintenance for which a separate schedule has been incorporated at the end of the section.

LEADING PARTICULARS.

Series No.	III.
Type of Engine	Air-cooled, in line.
Airscrew rotation	Anti-clockwise.
Method of Induction	Moderate Supercharge.
Supercharger Gear Ratio	5·041 : 1 (Crankshaft).
Drive to Airscrew	Single Spur Reduction Gear.
Reduction Gear Ratio	0·372 : 1 (Crankshaft).
Number of Cylinders	24, in four rows of six disposed in "H" formation.
Bore	3·8125 ins.
Stroke	3·75 ins.
Swept Volume (total)	1027 cu. ins.
Compression Ratio	7·75 to 1.
B.M.E.P. at Rated Power and Normal Speed,	159·7 lbs. sq. in.



Figs. 1 and 2.—Napier "Dagger" III, Starboard Side and Three Quarter Front Views.

Limiting Conditions.

Take-off and climb; to 1000 ft.

R.P.M. min.,	3000
R.P.M. max.,	3500
Boost max.,	Full Throttle (+3¼ lbs./sq. in.)
Cylinder Temp.,	210°C.

Climbing; over 1000 ft.

R.P.M.	3500
Boost, max.,	+2¼ lbs./sq. in.
Cylinder Temp.	270°C.

All-out Level (5 mins.)

R.P.M.	4000
Boost Max.	+2¼ lbs./sq. in.
Cylinder Temp.	240°C.

Cruising (continuous).

R.P.M. Max.	3500
Boost Max.,	+1¼ lbs./sq. in.
Cylinder Temp.	210°C.

Cruising (economical, 1½% drop in R.P.M.)

R.P.M., max.	3500
Boost, max.	+¼ lb./sq. in.

Terminal Velocity Diving.

R.P.M., momentary max.	4800

Engine Power (B.H.P.) at Altitude.

(*a*) Rated Power at +2¼ lbs. boost,	700/725 at 3500 R.P.M. at 3500 ft.
(*b*) Maximum Power at +2¼ lbs. boost	775/805 at 4000 R.P.M. at 5000 ft.

Engine Power (B.H.P.) at Sea Level.

I. *Flying at Rated Boost.*

(*a*) At 3500 R.P.M.	705
(*b*) At 4000 R.P.M.	735/760

II. *At M.P.B. for Take-off.*

(*a*) At take-off speed, min.	610/635
(*b*) At 3500 R.P.M.	730/755

Oil.

Pressure (main system)	30-40 lbs./sq. in.
Pressure (secondary system)	8-10 lbs./sq. in.

Pressure in secondary system is governed by an automatic reducing valve.

Oil specified	D.T.D. 109.	
Consumption	6 to 12 pints per hour.	
Inlet Oil Temperatures	Min.	40°C.
	Max.	80°C.
	Cold Starting	15°C.

FUEL.

Pump Pressure to Carburettor - -	1½ to 3½ lbs./sq. in.
Carburettor Fuel Head, minimum - -	2 ft.
Carburettor Fuel Head, maximum - -	10 ft.

CONSUMPTIONS.

(1) Cruising at 560 H.P. at 5000 ft. (3500 R.P.M.) ½ lb./sq. in. boost -	32½ galls. per hr.

The above consumptions are given at the maximum permissible power and speed allowed by the makers for continuous economical cruising.

(2) At 3500 R.P.M. at +2½ lbs. boost at sea level - - - - - -	54 galls. per hour.
(3) At take-off power at maximum permissible boost, at sea level, with enriched mixture - - - -	65 galls. per hour.
Fuel specified - - - - - - -	D.T.D. 230.
Weight—Nett, dry - - - - -	1285 lbs.
Gross, dry - - - - -	1332 lbs.
In running order - - -	1350 lbs.
Tolerance on weights - - - -	±2½ lbs.

IMPORTANT SETTINGS AND CLEARANCES.

General Running.

It is necessary at stated periods to check certain dimensions between adjustable parts such as make-and-break contacts, etc., and the following list gives the principal dimensions to note for adjustment while the engine is in service. Dimensions of such items as jets and valve timing are also given for checking at the stated times. Tappet clearances are not given, as the valve rockers embody hydraulically adjusted tappets, and thereby obviate the necessity for adjustment.

NOTE.—The items " Port " and " Starboard " as indicated by the letters " P " and " S," are sometimes used in the marking of the parts on these engines as alternatives to L.H. and R.H. markings invariably referred to in these notes.

(1) VALVES (Fig. 26).

Timing.—The valves are timed with dummy rockers, according to procedure given on page 267 *et seq.*, to the special figures as given below.

Inlet opens	2½° Early.
Inlet closes	32½° Late.
Exhaust opens	41½ Early.
Exhaust closes	6½° Early.
Inlet Valve Lift (cold), no clearance	0·434 ins.
Exhaust Valve Lift (cold), no clearance	0·434 ins.
Tolerance on Valve Timing	$\pm$ 5°

The engine is timed on Nos. R.H.1, L.H.6, R.H.9, L.H.10 cylinders.

IGNITION. (Figs. 15 and 16).

MAGNETOS (2 fitted).

Makers	The British Thomson-Houston Co., Coventry, England.
Type	C.S.E. 12-12S.

Direction of rotation looking on driving end :—

L.H. Magneto	Anti-clockwise.
R.H. Magneto	Clockwise.
Speed of rotation	1·5 times crankshaft speed.
Number of make-and-break contacts,	2 sets per magneto.
Make-and-break Gap	0·0115 to 0·013 in.

DISTRIBUTORS (2 fitted).

Direction of rotation looking on driving end :—

L.H. Distributor	Anti-clockwise.
R.H. Distributor	Anti-clockwise.
Distributor Gap	0·010 to 0·012 in.
Speed of Rotation	0·5 times crankshaft speed.
Number of Points per Distributor	24
Number of H.T. Distributor Brushes	2 per Distributor.
Sparking Plugs	K.L.G. type B.862D. with screens type M.S.D.
Sparking Plug Gap	0·015 in. to 0·015 in.

TIMING. (Automatically Variable). Engine timed with full advance on No. L.H. 1. Cylinder according to procedure on page 270, *et seq.*

	L.H. Magneto.	R.H. Magneto.
Full Advance (inside cam) - - - -	45° Early.	45° Early.
,, (outside cam) - - - -	41½ ,,	41½ ,,
Tolerance on ignition timing - - - -	±1°	

Full retard, occurs 15° later than the above figures.

CYLINDER NUMBERING. (*Note*—This commences at the rear end).

	L.H. Top.								R.H. Top.						
Rear	1	2	3	4	5	6	Front.	Rear	1	2	3	4	5	6	Front.
	12	11	10	9	8	7			12	11	10	9	8	7	
	L.H. Bottom.								R.H. Bottom.						

FIRING ORDER.

L.H. - - -	1	9	5	12	3	8	6	10	2	7	4	11	
R.H. - -		10	2	7	4	11	1	9	5	12	3	8	6

The cylinders fire in sequence as above.

CARBURATION.

CARBURETTOR. (Fig. 18).

Makers - - - - - - - - -	Messrs H. M. Hobson Ltd. Acton Vale, London, W.3. England.
Type - - - - - - - - -	A.I.T. 80 B/3.
2 Choke Tubes - - - - - - -	72 mm. diameter each.
2 Main Jets - - - - - - - -	2000 cc.
1 Power Jet (opening at 65-67% of throttle pick-up lever movement, from "closed" position), -	600 cc.
2 Slow-running Jets - - - - -	475 cc.
2 Enrichment Jets - - - - -	125 cc.
Working Head, min., - - - - -	2 ft.
Working Head, max., - - - -	10 ft.
Fuel level below joint face, min. head -	41 mm. — 1½ mm. + 1
,, ,, ,, max. head -	34½ mm. — 1½ mm. + 1
Mixture Control - - - - -	46·3 per cent.

LUBRICATION. (Figs. 21, 22, 23).

The relief valve is set and locked at the manufacturers' works to give an oil pressure gauge reading of 30-40 lbs. per sq. inch when the oil is hot and the engine turning over at 3500 R.P.M. The pressure in the secondary oil system is controlled by an automatic reducing valve from the main system.

The relief valve must not be used as a means of adjusting the oil pressure when the engine is in service, until all other methods of correcting the pressure have failed.

LUBRICATING OIL.

The lubricating oil given in Leading Particulars, *i.e.*, D.T.D. 109, is the standard Air Ministry specification for oil approved for use in "Dagger" Series III. engines. A number of proprietary brands of oil to this specification are available and any one can be used. It is not permissible to use mineral oil to any specification *other* than D.T.D. 109 and under no circumstances must castor base oils be used. When a change of oil is required, as in " Maintenance Schedule," it is essential to remove as much of the old oil as possible to minimise contamination. The engine should first be well warmed up and the aircraft oil system disconnected and allowed to drain thoroughly. The Tecalemit pressure filter elements must be changed, the scavenge strainer chambers and pump casing emptied and the oil in the bottom camshaft casings drained by removing the small drain plugs in the covers. When refilling after changing oil, it is important that all air be driven out of the system and that all pipe joints are tight. This is of special importance on the feed pipe from the tank to the engine as if faulty or not primed, the suction of the pressure oil pump will be impaired.

The engine should also be primed thoroughly with hot clean oil before restarting, after changing the oil.

DESCRIPTION.

General.—The "Dagger" Series III. Aero-engine is a twenty-four cylinder air-cooled supercharged engine having the cylinders in four rows of six, disposed in "H" formation on the crankcase (Fig. 3).

Each vertically opposed pair of rows drives a crankshaft, the two crankshafts being geared to a common airscrew-shaft in the front cover, at the forward end of the crankcase. The valve gear of each row of cylinders is operated by a single overhead camshaft which is driven from the timing gear at the rear end of the crankcase. The timing gear is driven from the rear end of the airscrew shaft by a tubular centre shaft. The timing gear casing supports the accessories, starter and oil pump unit.

The ignition system comprises two double magnetos, cross connected to two 24 point distributors, these items being driven from the airscrew shaft.

The induction system comprises an inverted twin-choke carburettor, supplying mixture through an oil jacketed volute, to a centrifugal type supercharger, whence it passes via a delivery volute to the cylinders. The supercharger is mounted behind the timing casing, and is driven from the centre shaft.

Crankcase (Figs. 4 and 5).—This is in halves held securely together by long fitted bolts, and incorporates the induction tunnels leading from the supercharger delivery volute to the induction pipes. The crankcase is heavily cross-webbed and houses the crankshaft main bearings and the airscrew rear bearing.

The crankcase also carries the front cover at the forward end, and the timing casing at the rear end, both which are spigot mounted.

The crankcase is provided with four long studs round each cylinder aperture to hold the cylinder heads down on the barrels. Spigot facings are provided on the sides of the crankcase for attaching the engine feet.

The Front Cover (Fig. 6).—This houses the airscrew shaft, reduction gear, and thrust bearing, and also carries the drives for the magnetos and distributors which are mounted separately.

Housings are incorporated on each side of the airscrew shaft for the forward bearings of the two crankshaft reduction gears.

The airscrew shaft is geared to the two crankshafts by a single spur reduction gear and also drives the tubular centre shaft, which in turn drives the timing gear and supercharger.

Cylinders and Valve Gear (Figs. 7 and 8).—The cylinders are separate and have close-finned steel barrels, but the forged aluminium alloy heads are assembled as a unit with the camshaft casings. An aluminium sealing ring is fitted between each cylinder barrel and its head.

Stellited steel inserts shrunk into position are utilised for valve seats in the cylinder heads.

Each camshaft casing houses a single camshaft and rockers operating two valves per cylinder. These rockers are each provided with hydraulically operated tappets which obviate the necessity for tappet adjustment (See Fig. 9).

The camshafts are driven by bevel gears and shafts from the timing,

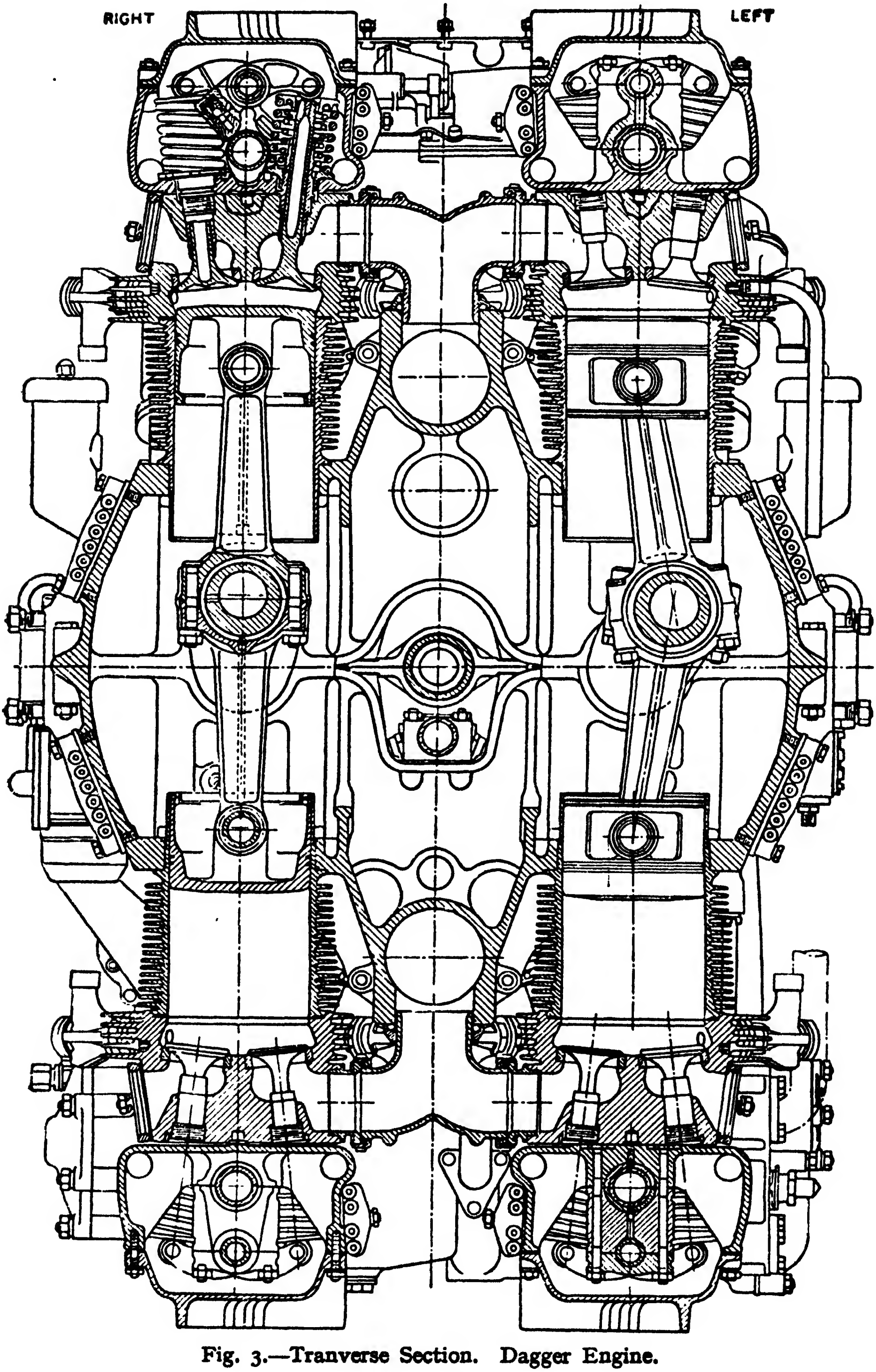


Fig. 3.—Tranverse Section. Dagger Engine.

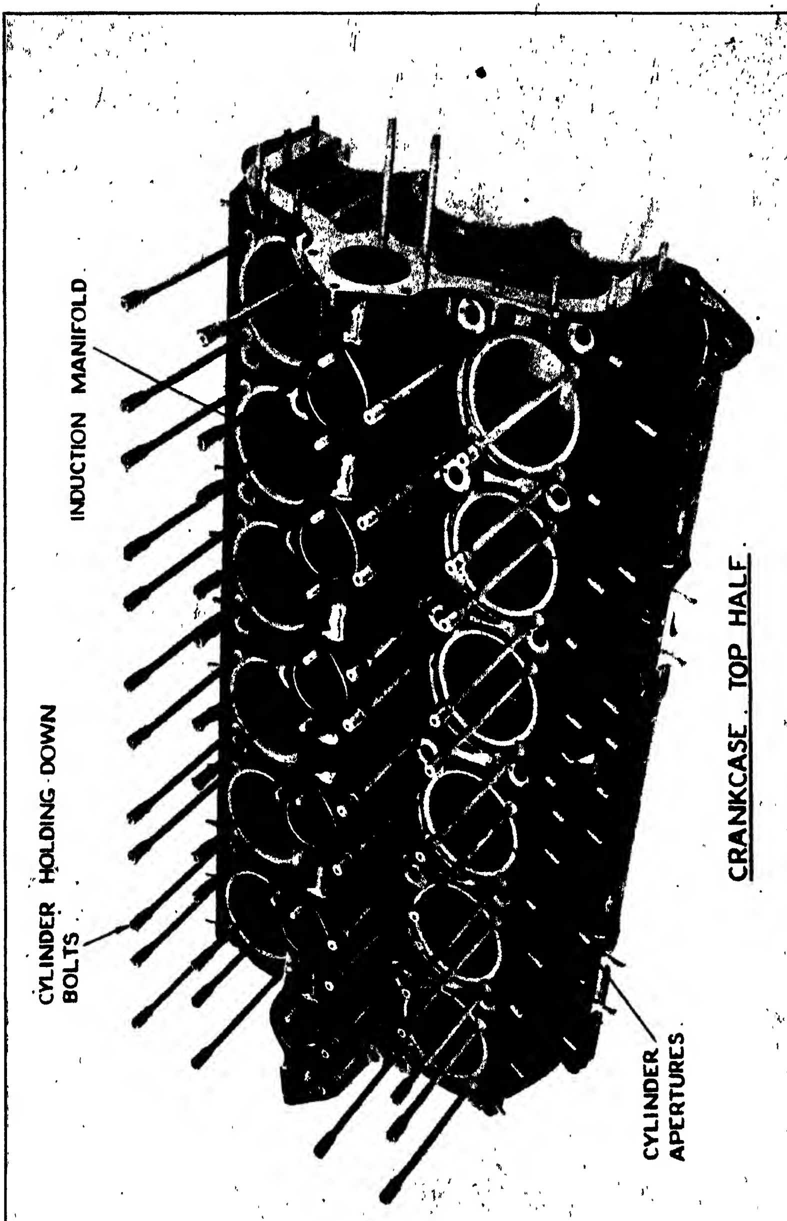

INDUCTION MANIFOLD
CYLINDER HOLDING DOWN BOLTS
CYLINDER APERTURES
CRANKCASE . TOP HALF .

Fig. 4.

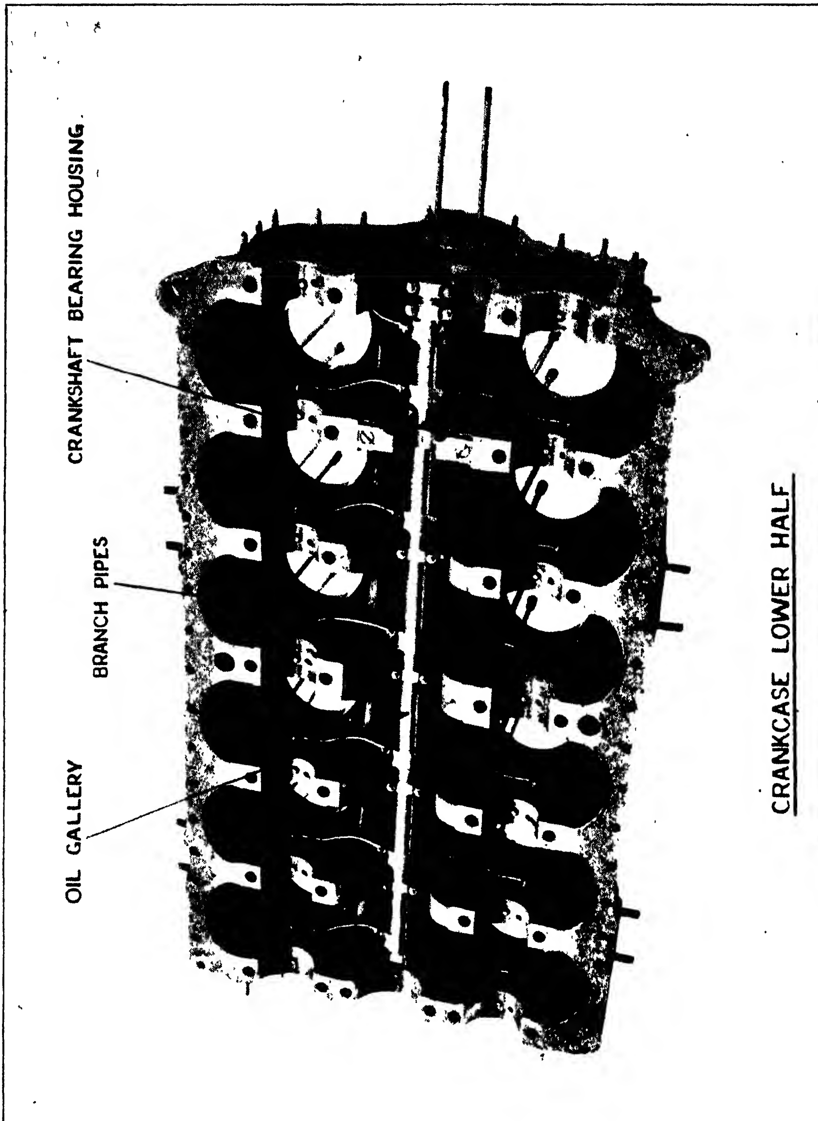

CRANKSHAFT BEARING HOUSING.
BRANCH PIPES
OIL GALLERY
CRANKCASE LOWER HALF

Fig. 5.

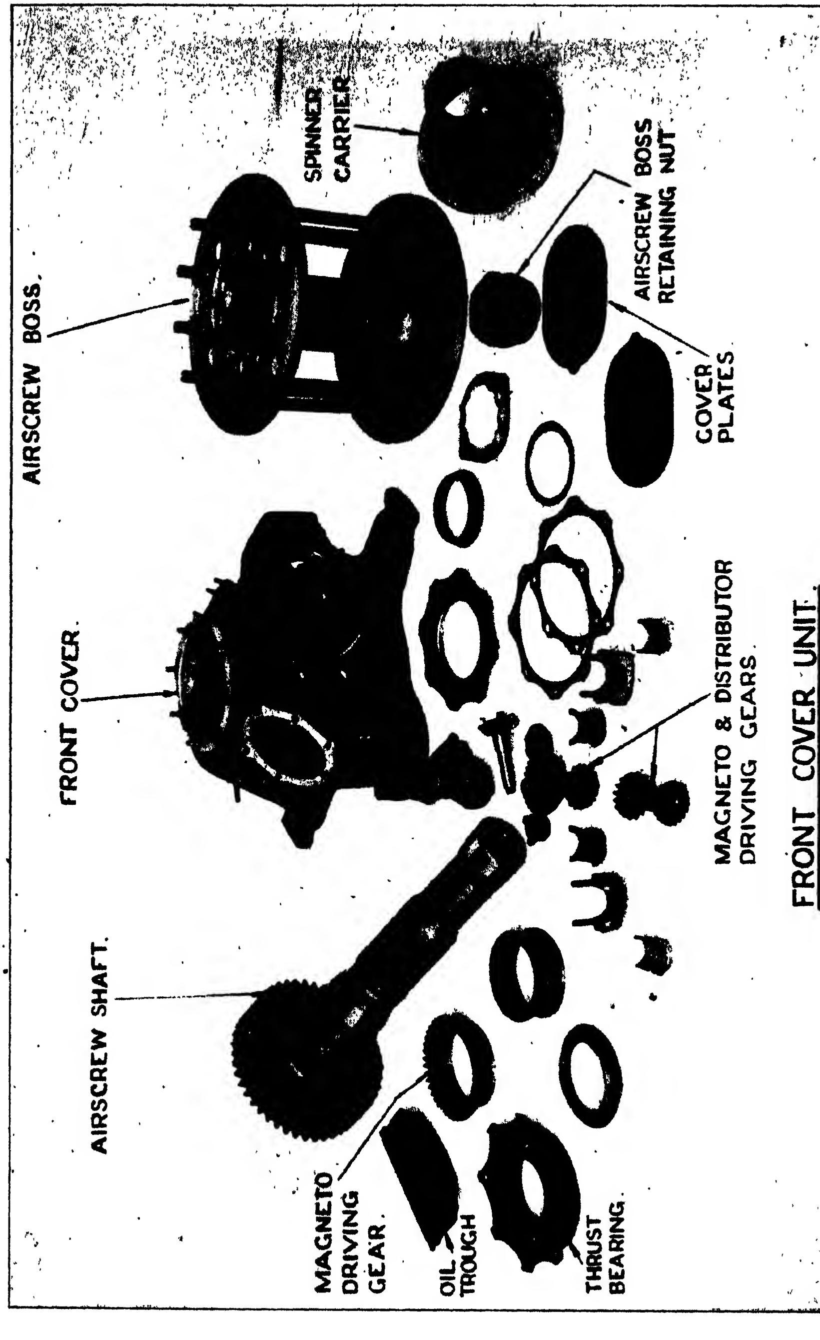
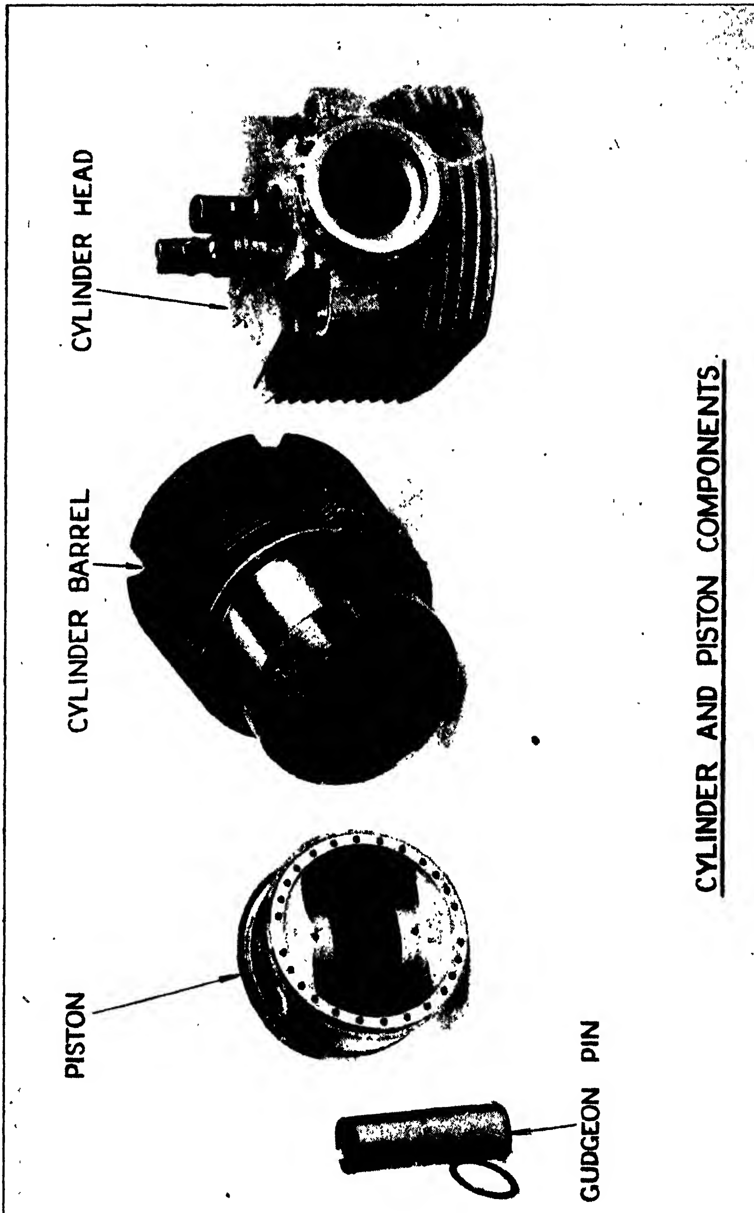

AIRSCREW BOSS.
SPINNER CARRIER
AIRSCREW BOSS RETAINING NUT.
COVER PLATES
FRONT COVER.
MAGNETO & DISTRIBUTOR DRIVING GEARS.
AIRSCREW SHAFT.
MAGNETO DRIVING GEAR.
OIL TROUGH
THRUST BEARING.
FRONT COVER UNIT.

Fig. 6.



CYLINDER AND PISTON COMPONENTS.

Fig. 7.

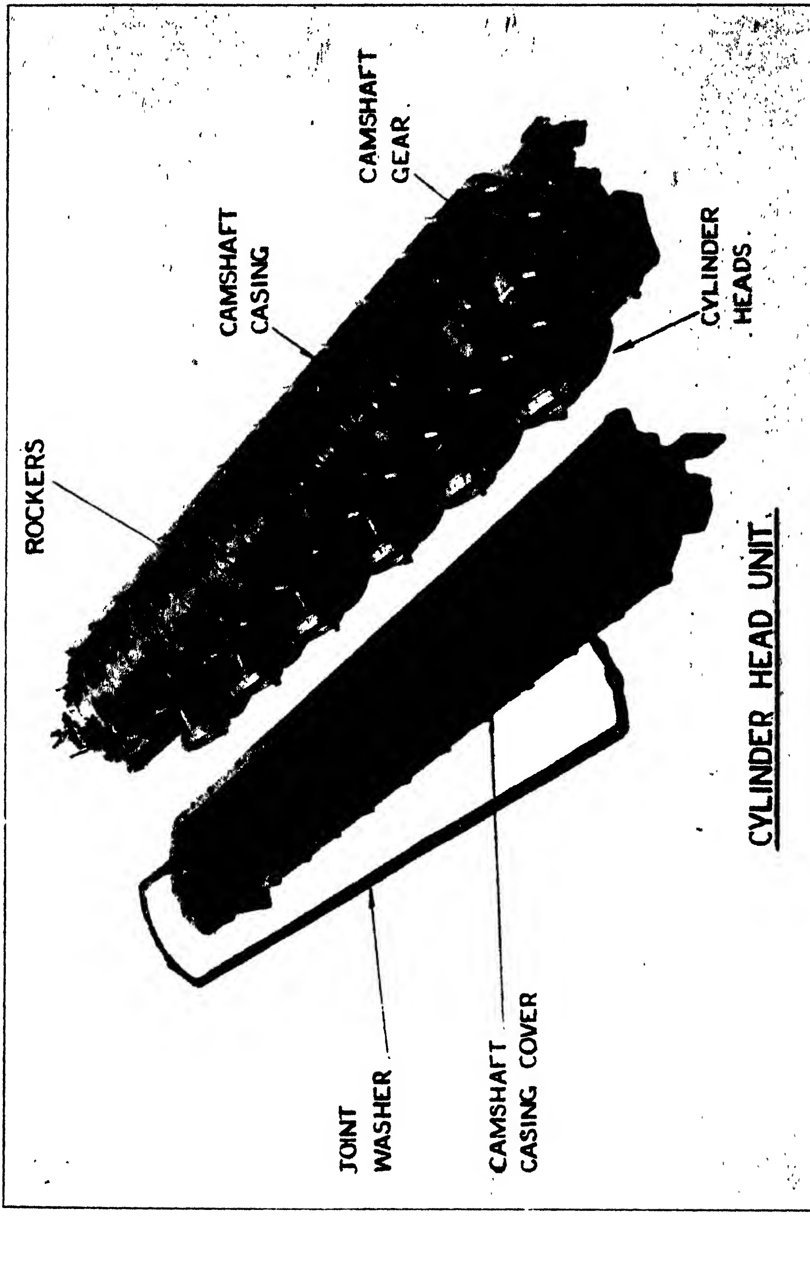

CAMSHAFT GEAR
CAMSHAFT CASING
ROCKERS
CYLINDER HEADS
CYLINDER HEAD UNIT
JOINT WASHER
CAMSHAFT CASING COVER

Fig. 8.

casing. These shafts are housed in cover tubes fitted with glands at their inner ends.

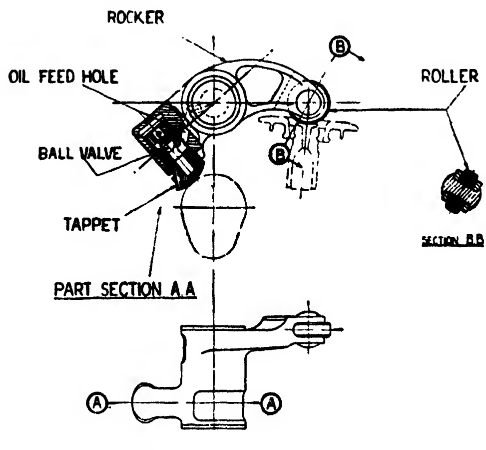
The cylinders are provided with air deflector plates and air chutes to ensure an adequate supply of cooling air.

The exhaust valves have Nitrided stems, Stellited seating faces and stem ends, and are sodium cooled.

The inlet valve faces are not Stellited.

Pistons and Connecting Rods (Figs. 7 and 12).—Full skirted forged aluminium alloy pistons fitted with fully floating gudgeon pins are used. Two gas rings and one scraper ring are fitted to each.

The connecting rods are arranged in pairs, comprising one plain and one forked rod, and each pair has a common lead bronze bearing dowelled to the forked rod.



ROCKER WITH HYDRAULIC TAPPET

Fig. 9.

Fixed bronze bushes are used in the small ends, and are lubricated under pressure through ducts drilled up the centre webs of the rods.

Crankshafts (Fig. 12).—These are of orthodox design, and have a bearing between each throw. They are drilled and bored for lightness and passage of oil, and the throws and journals are plugged. The forward ends carry spur reduction gears on tapered extensions, keyed and secured with retaining nuts. The two crankshafts are set 30° out of phase in order to give even firing sequence.

The rear end of the L.H. crankshaft is fitted with a short coupling shaft and a bevel gear which meshes with a short inclined shaft, carrying a dog at its outer end, for the inertia starter.

Timing Casing (Fig. 10).—This casting is bolted and spigoted to the rear of the crankcase. It carries the four camshaft inner drive shafts, of which the top and bottom pairs are driven through short bevel drives from a central bevel gear. The latter is driven by the tubular centre shaft, and

has a second bevel gear of smaller diameter bolted to it. This drives a short horizontal intermediate shaft to which a cross shaft is geared.

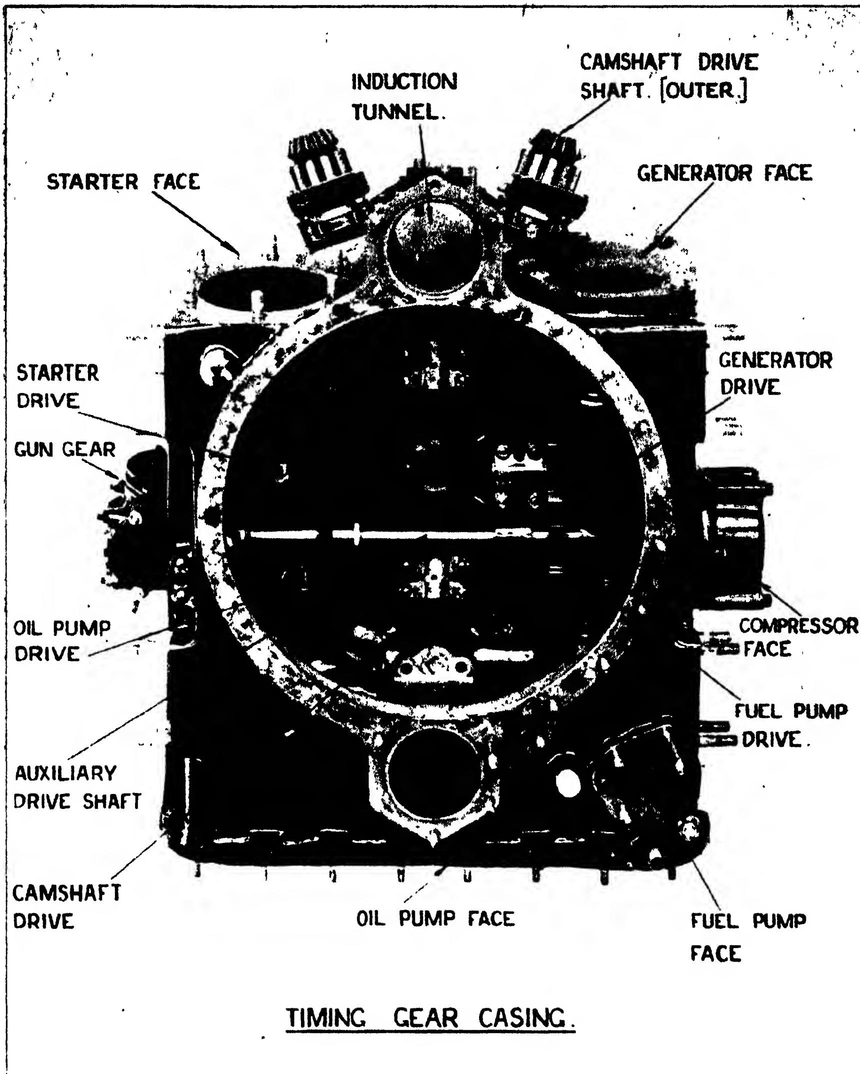
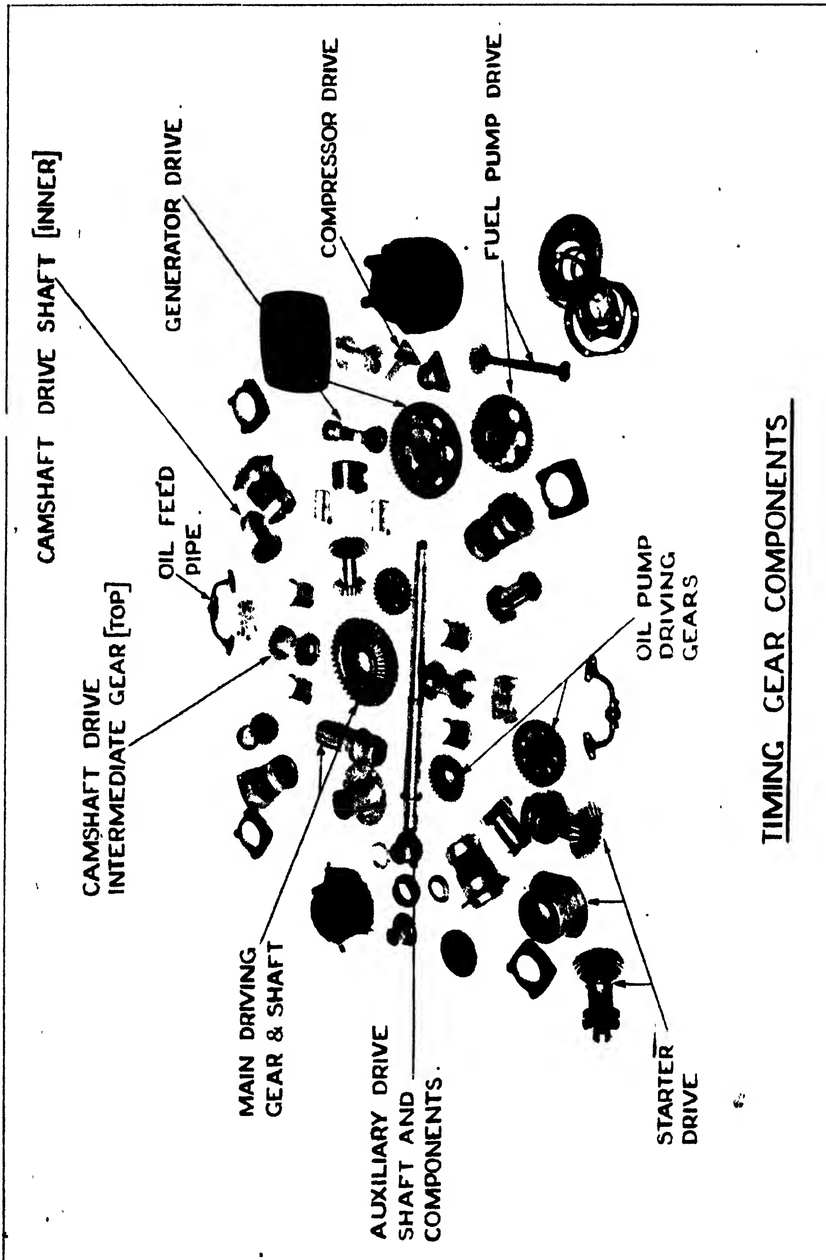


Fig. 10.

This cross shaft drives the accessories on the outside of the timing casing directly, and through short intermediate shafts and gears.

Pressure fed plain bearings are utilised throughout, in the drives for the timing gear and accessories, except in the thrust bearing for the inertia



TIMING GEAR COMPONENTS

Fig. 11.

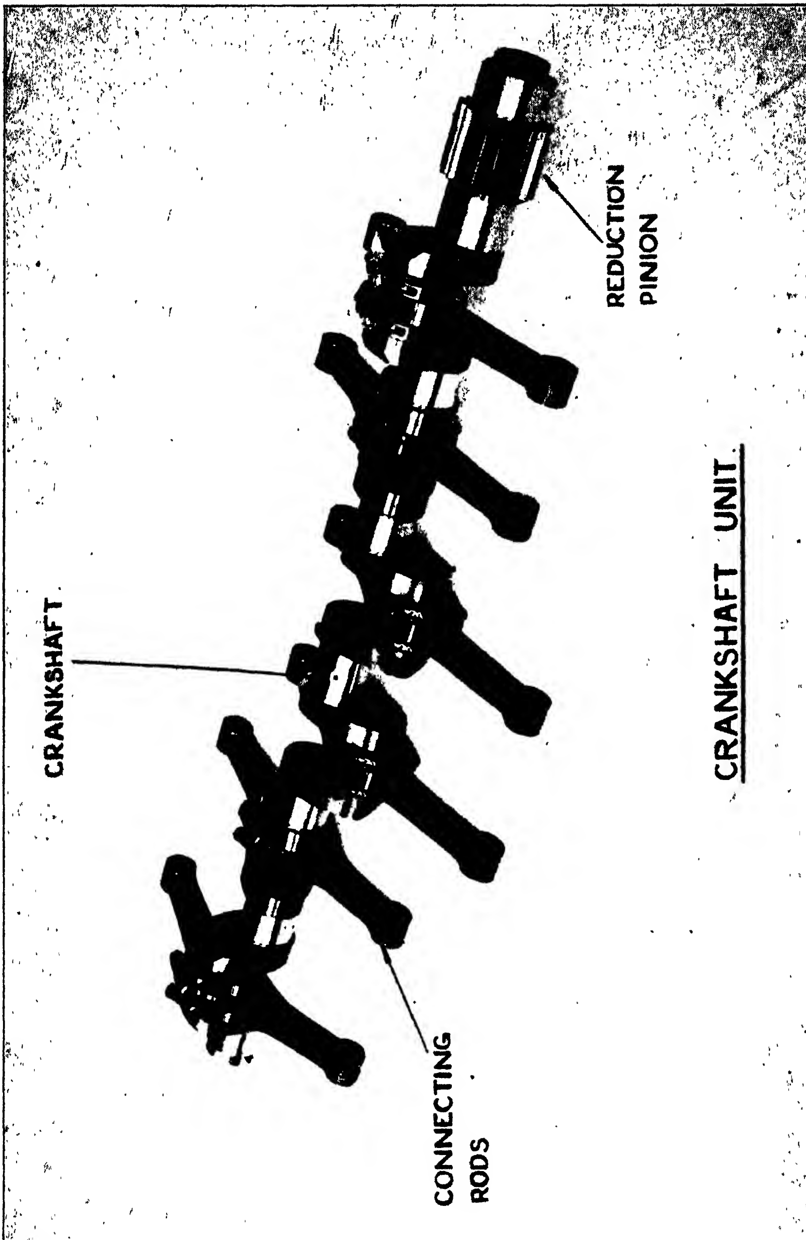

REDUCTION
PINION
CRANKSHAFT
CRANKSHAFT UNIT
CONNECTING
RODS

Fig. 12.

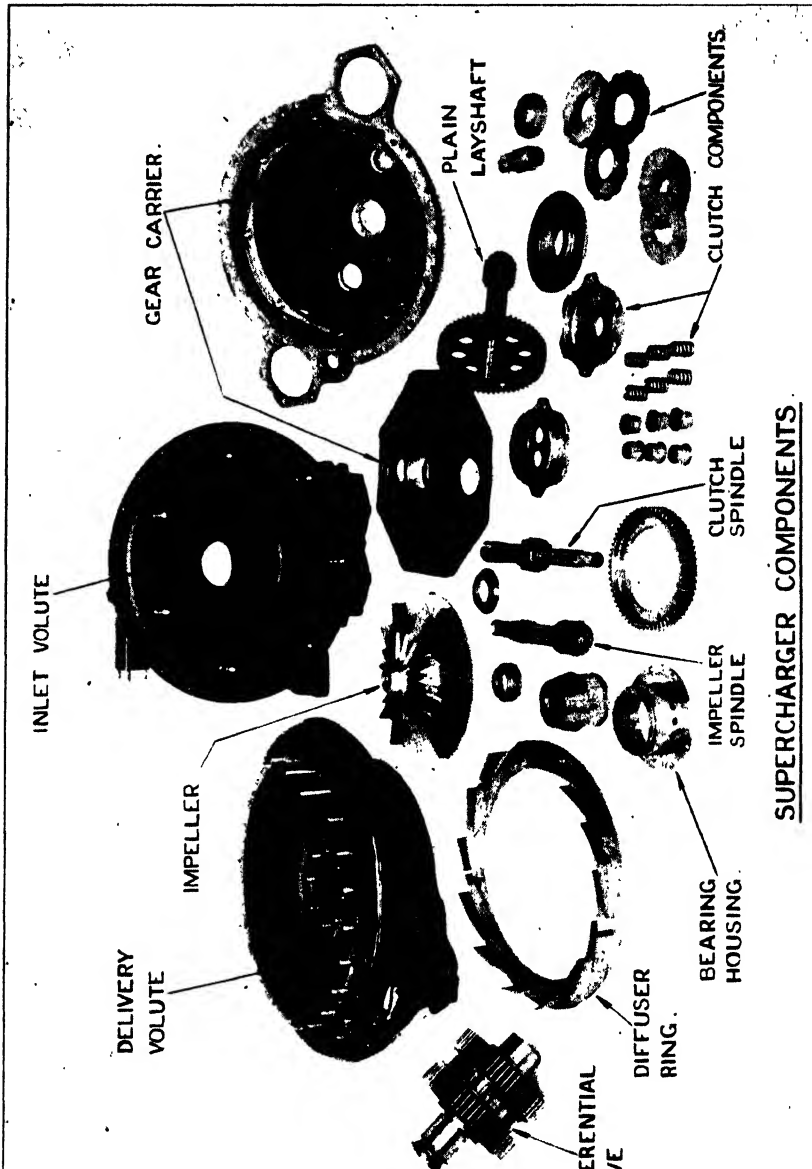

GEAR CARRIER.
PLAIN LAYSHAFT
CLUTCH COMPONENTS.
INLET VOLUTE
CLUTCH SPINDLE
IMPELLER
IMPELLER SPINDLE
SUPERCHARGER COMPONENTS.
DELIVERY VOLUTE
BEARING HOUSING.
DIFFUSER RING.
DIFFERENTIAL DRIVE

Fig. 13.

starter extension shaft. The casing is drilled and fitted with the necessary piping to lead the oil where required.

Supercharger (Fig. 13).—This comprises an oil jacketed inlet volute from the carburettor, spigoted into the main delivery volute which houses the impeller.

The delivery volute is spigoted and bolted to the rear end of the timing casing, and carries a large housing in which the supercharger drive is mounted.

The power to drive the supercharger is taken from the rear end of the centre shaft, by means of a short coupling shaft, to the central spindle of the supercharger increasing gear which carries a differential gear. The latter distributes the power equally to two large spur gears which drive the two supercharger layshafts. One of these is a plain shaft and drives the supercharger impeller direct, and the other embodies a spring loaded multi-plate clutch to protect the drive from sudden overload. (See Fig.)

The supercharger impeller is mounted on a stiff shaft carried in ball bearings housed in the front wall of the delivery volute casing and in the centre of the inlet volute.

Oil Pump Unit (Figs. 14, 21 and 23).—This is embodied in a casting at the bottom of the timing casing, and incorporates two gear type scavenge pumps drawing oil through two concentric gauze strainers.

These pumps are superimposed, and below them is the pressure pump, which also drives a small metering pump supplying oil to the rear bearing of the supercharger impeller.

A hollow chamber, behind the pumps, houses a Tecalemit filter element, and this chamber is provided with a pressure release valve in case of an emergency.

The high pressure oil is controlled by a relief valve in the L.H. end of the pump casing, and the low pressure is governed by a pressure reducing valve below the relief valve. To adjust the relief valve, unlock and remove the cap, loosen the locknut on the adjusting screw and turn the latter as required. Retighten the locknut, refit the cap and lock with wire. Turning the screw anti-clockwise will raise the pressure and vice versa.

The pressure reducing valve comprises a piston with two diameters which are such as will give the correct proportion of pressure reduction. High pressure oil, admitted to the smaller diameter, forces the piston out until a port and passage therefrom, leading to the larger diameter, is opened. The pressure on the larger diameter forces the piston in again and closes the port, and the pressure on the larger diameter falls.

The piston therefore moves out and the port is opened again. Thus a steady pressure lower than that in the high pressure circuit is maintained in the passage between the ends of the piston. This passage feeds the low pressure circuit. Should it be desirable to remove the reducing valve, detach the triangular cover plate and draw the valve out for cleaning.

The pump casing also forms a sump into which all the scavenge oil from the engine collects, before passing via the scavenge pump to the tank. A spring-loaded drain valve in this sump closes automatically when the scavenge strainers are removed, and prevents any loss of oil from the sump while this is being done. The circulation of the oil is described under "Lubrication System".

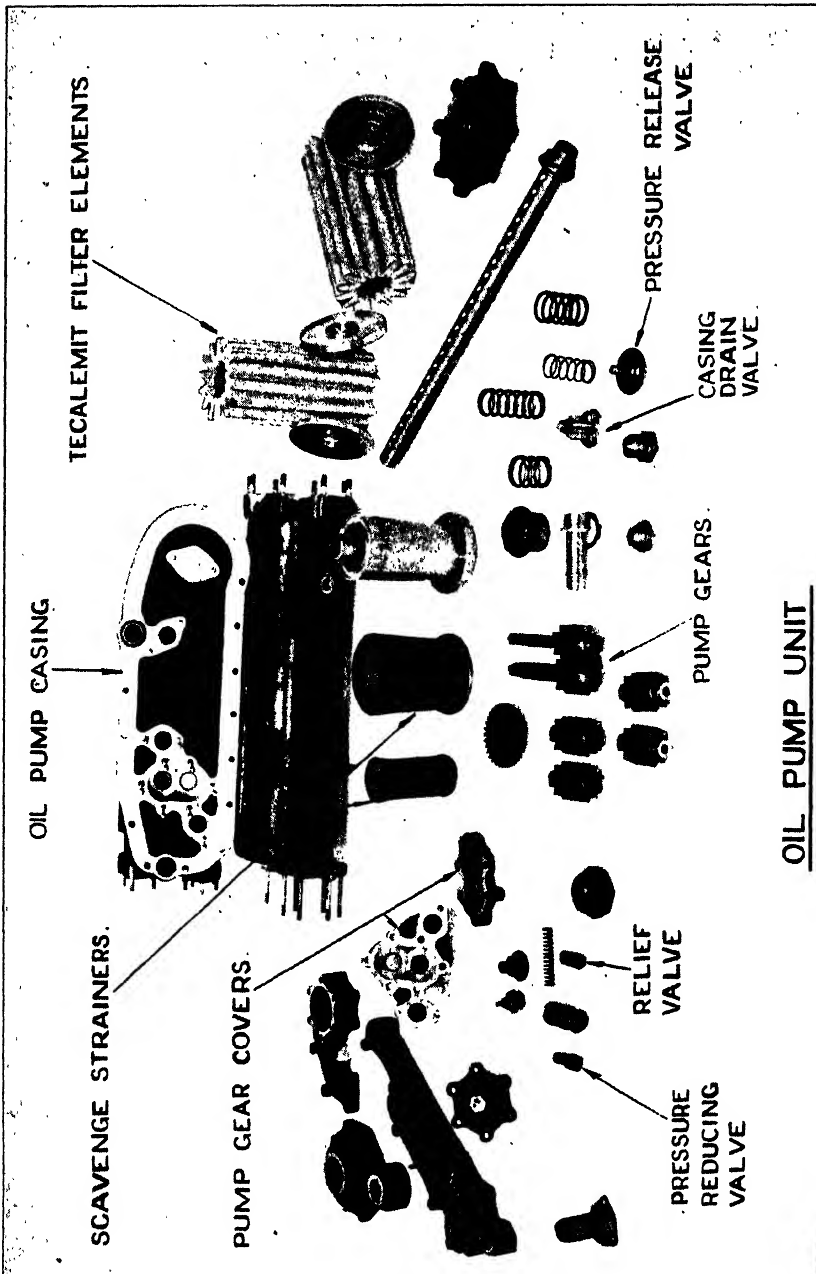

OIL PUMP UNIT
TECALEMIT FILTER ELEMENTS
PRESSURE RELEASE VALVE
CASING DRAIN VALVE
OIL PUMP CASING
PUMP GEARS
SCAVENGE STRAINERS
PUMP GEAR COVERS
RELIEF VALVE
PRESSURE REDUCING VALVE

Fig. 14.

Fuel Pump and Relief Valve.—The fuel pump with integral relief valve is of the meshed spur gear type, and is located at the R.H. bottom corner of the timing casing. A by-pass valve is also incorporated, to enable fuel under pressure by hand-pump to by-pass the pump gears, in order to fill the carburettor.

Ignition System (Figs. 15, 16 and 17).—The ignition system differs somewhat in arrangement from the orthodox type, but the principles employed are the same. Two B.T.H. C.S.E. 12-12S Magnetos (each of which is really a double magneto and thus equal to two 12-cylinder magnetos), and two independently driven 24-point distributors are arranged at the front of the engine. One distributor is arranged to fire all "inlet" plugs and the other, all "exhaust" plugs. The distributors are not wholly energised by any one magneto, half the number of points of each being energised by half the R.H. magneto and the other half by half the L.H. magneto. Each magneto is fitted with two heavy gauge, specially insulated leads, one to each distributor.

The usual braided cables connect the distributors to the screened sparking plugs. These screens are detached by pressing the knurled knob inwards, turning anti-clockwise and drawing from off the sparking plug. To dismantle, unscrew the milled nut which holds the H.T. cable into the screen body and withdraw the cable. When testing for electrical leakage, fit the H.T. testing wire to make contact with the sparking plug terminal and with 100 lbs. per sq. in. pressure applied to the plug points, observe whether the spark is passing across the points or shorting through the insulation of the screen. Provision is made for connecting four "off and on" switches to the low tension circuits, to interrupt the current in the four wires connecting the magnetos to the distributors, when required.

Thus two switches will control the current to the "inlet" plugs and the other two the "exhaust" plugs. The two "inlet" and the two "exhaust" switches should be coupled together so that the pilot, when checking the ignition with the engine running, will switch, off or on, all "inlet" plugs or all "exhaust" plugs in one movement. This arrangement ensures that during the test, with the ignition functioning normally, at least one sparking plug per cylinder is in action. The interconnecting bars, if suitably designed, can be removed to check the running on independent switches, but when doing so it must be remembered that switching off any one magneto, *i.e.*, switching off say the "left magneto, inlet" (L.M.I.). switch and the "left magneto, exhaust" (L.M.E.) switch at the same time, will result in switching off the whole of one side of the engine (the left side in the above case), a procedure which *must* be avoided. For the recommended method of testing the ignition system with engine running, see page 257.

The following procedure must be observed when replacing the distributors, to avoid damage to the distributor brushes due to fouling the segments. Turn the engine so that the brush holder is set to the marks on the spigot of the distributor base plate, so that the wide arm points to the wide mark, the narrow arm points to the narrow mark, and the third arm points to the other wide mark on the base plate. The distributor is to be fitted straight down on to the base, keeping the black line engraved on it coinciding with the line on the base.

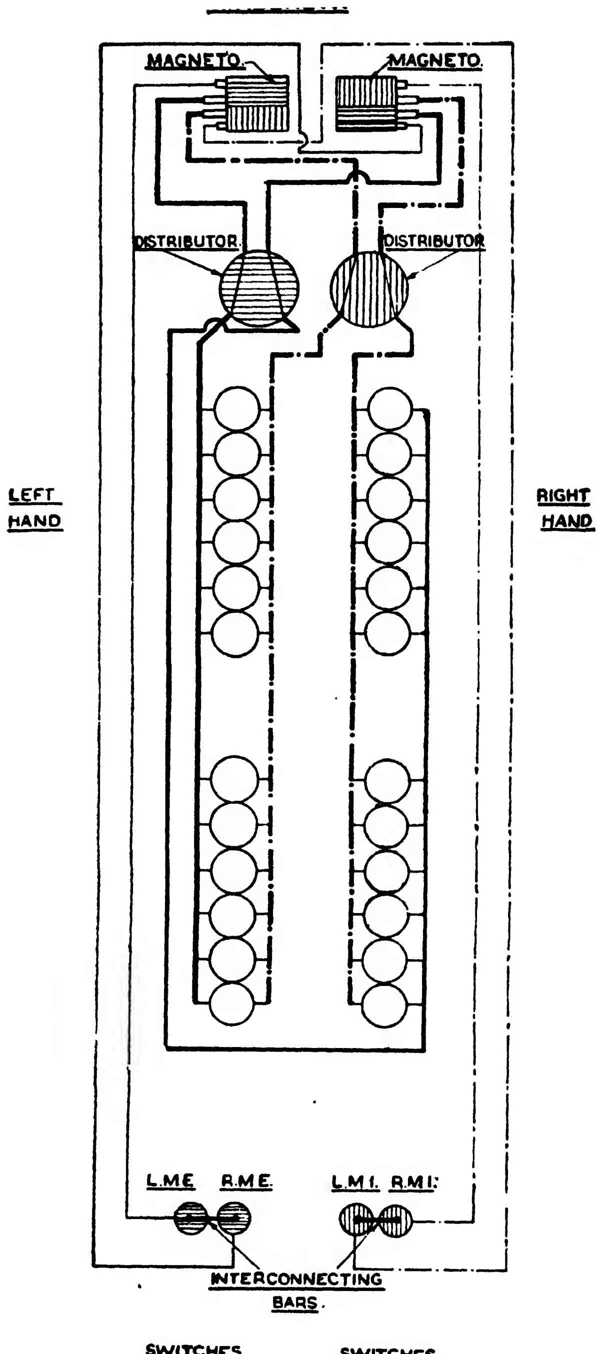


Fig. 15.—Ignition System (Diagrammatic)—Dagger III.

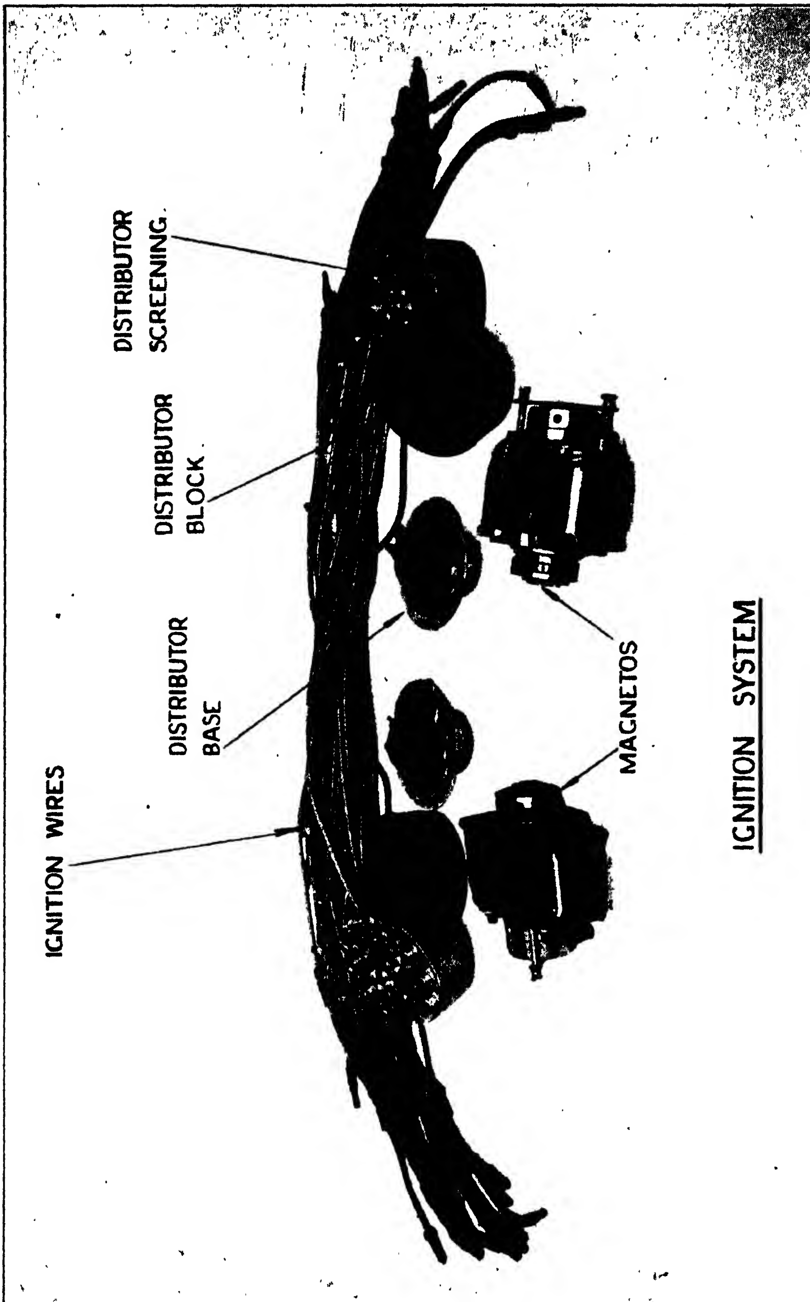

IGNITION WIRES
DISTRIBUTOR BASE
DISTRIBUTOR BLOCK
DISTRIBUTOR SCREENING
MAGNETOS
IGNITION SYSTEM

Fig. 16.

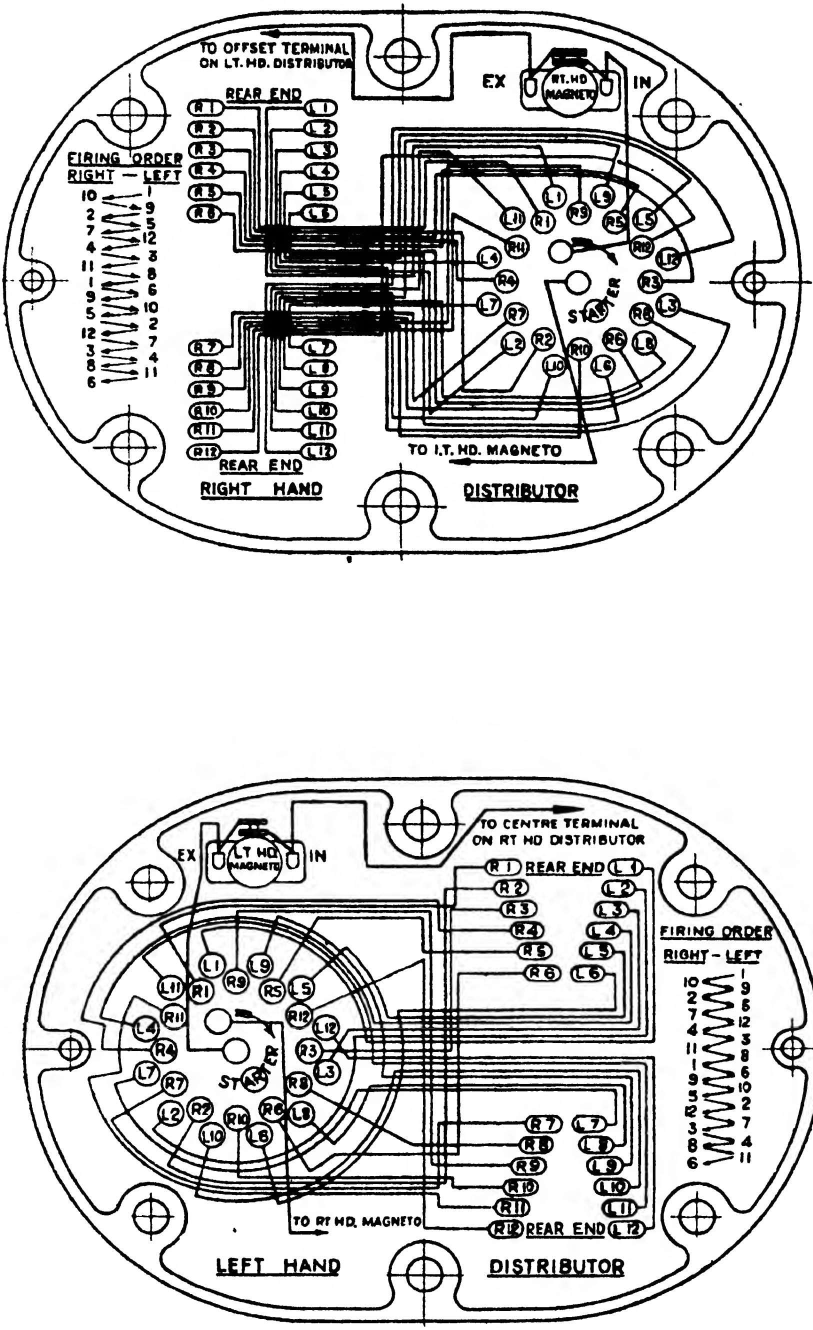


Fig. 17.—Ignition Wiring Diagram—Dagger.

Description.—The Carburettor (Fig. 18) is of the twin choke inverted type and embodies the customary Claudel Hobson features such as the diffuser tubes, air leak type of mixture control and submerged jets, which in the case of the power and enrichment jets are plunger operated as shown in the diagram.

The main body of the carburettor is in halves bolted together with a joint washer between the faces.

The lower half incorporates the float chamber in which the two cork floats and their needle valves are located, and also the two main jets, a single power jet, two slow-running, and enrichment jets.

The passages which lead fuel from the float chamber to the jets and thence to the diffusers and choke tubes, are drilled through bossed portions of the carburettor body lower half which also houses the plunger valves which control the enrichment and power jets. All jets can be readily removed for inspection.

The accelerator pump which is also housed in the body lower half, comprises a piston operated through the control linkage from the throttle pick-up lever. The piston itself houses the inlet check valve, and the outlet check valve is housed in the delivery passage from the pump to the choke at the point where it crosses the joint face to the carburettor body top half. The pump delivers a charge of fuel into the bore of the chokes as the throttle is opened.

The choke tubes are detachable, and each is secured in position in the carburettor body by a retaining screw. A streamlined fairing piece surrounds the main emulsion delivery tubes and, in the case of one choke, the power jet delivery tube also, which projects into the chokes, in order to minimise any tendency to turbulence in the throat of the choke.

The throttle butterfly valves are mounted on a common spindle to which they are attached by flat retaining plates with set screws. The valves have transverse passages to lead slow running mixture to both sides of the valves. The chokes are oil-jacketed to prevent freezing.

It was found that, with earlier models, it was possible for the pilot to open the valve controlling the enrichment jet, by moving the mixture control lever to "override rich", with the engine idling before take-off. Excess fuel was therefore drawn into the induction system and the engine thereby rendered liable to choke when the throttle was opened for take-off. A second valve, known as the series valve, is now incorporated in the fuel passage to the enrichment jet and is controlled through the same linkage as the power jet from the throttle pick-up lever, so that the enrichment jet is not brought into action until the throttle pick-up lever is moved to "open."

But when the throttle is fully open as at "All-out level" position in flight, the mixture control is in the "Normal rich" position and the enrichment jet valve is now closed. Thus the use of the enrichment jet is ensured only when the throttle pick-up lever is opened for take-off with enriched mixture.

The upper half of the carburettor body incorporates the air intake flange, which is flared into the choke bores, and houses the twin mixture control valves, the cross-shafts and linkage operating the accelerator pump, the various jet valves, and the two pressure balance pipes.

The latter project into the air intake flare and provide an intake for air to the mixture control valves.

The mixture control comprises two cone shaped valves held by light springs on to their seats. The valves are situated in the carburettor body top half in the passage from the pressure balance tubes, and are connected to the passage from the main diffusers to the main emulsion delivery tubes.

Air for the diffuser tubes is drawn into a cored portion of the body top half through a number of small holes drilled through the main air intake flare at this point and passes downwards through a duct leading to the annulus surrounding the diffuser tubes. A small hole admits air from the cored portion to the top of the float chamber to equalise the pressure between it and the air intake.

The fuel feed to the slow-running system is taken from the main jets through slow-running tubes fitted in the bottom of the diffuser wells. The tubes are connected by passages to the slow-running jets and by further drilled passages to a cut-off valve located between the two main bores in the body upper half. This comprises a spring loaded sleeve which uncovers or covers a port leading to the slow-running holes at the throttle valve edge.

An air adjusting cock is located above the cut-off valve to control the air admitted to the slow-running system. This comprises a sleeve having a calibrated port cut in it and provided with a graduated notched adjustment. Air holes connect the cock with the air intake flare and a further passage connects the cock to the cut-off valve, and a drilled passage connects the cut-off valve with the slow-running holes at the throttle edge.

Adjustment of Slow-Running Mixture.—Release the locking wire and lock-nut of the air cock and run the engine at idling speed. Turn the knurled ring as required to obtain even running.

The numbers on the graduations are arranged so that more air is admitted as the numbers increase and vice versa. Having obtained satisfactory adjustment, re-tighten the locknut, and wire.

Operation.—The action of the carburettor is as follows :—

(*a*) *Slow Running.*—Throttle butterfly barely open. Main, power, and enrichment jets out of action. Suction on slow-running holes causes air to enter adjusting cock from air intake flare whence it passes to the cut-off valve. Fuel from main jets to diffuser wells passes through slow-running tubes to slow running jets and so to cut-off valve. Here it mixes with air from cock and passes as an emulsion to the slow-running holes at the throttle edge.

(*b*) *Taking-off and Climb to* 1000 *feet.*—Mixture control moved to " override rich " position causes cam to open enrichment jet valve. When throttle is opened, series valve opens and brings enrichment jet into action. Increased throttle opening causes slow-running jets to gradually drop out of action as increased suction on main choke delivery tubes brings main and power jets into action. Main jets deliver fuel to diffusers where it meets air coming through holes in diffuser tubes and mixes with it to form an emulsion which passes to choke delivery tubes. Power jet delivers fuel to power jet delivery tube in one choke. As fuel level in diffuser wells falls, more holes in diffuser tubes are uncovered and mixture strength is compensated automatically. Fuel level eventually falls below level of slow-running tubes and the supply to slow-running system is cut off.

As throttle is opened, accelerator pump forces a small charge of fuel

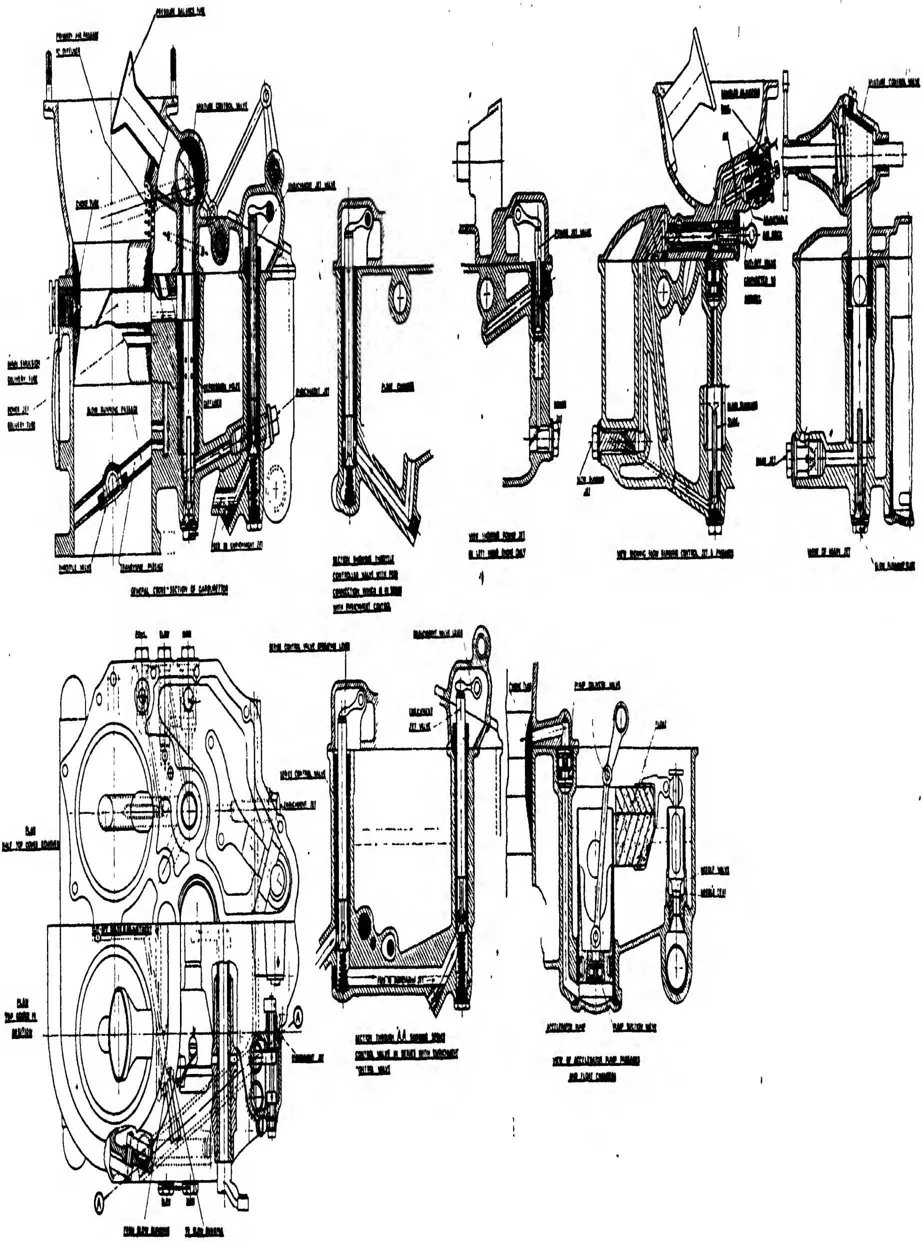


Fig. 18.—Carburettor.

into each choke to counteract any tendency for engine to falter while picking up.

(*c*) *Climb above* 1000 *feet.*—

Mixture control moved to " normal rich."

Enrichment jet valve and jet out of action.

Throttle valves as far open as boost control will permit for climbing boost conditions.

Main and power jets in full action.

(*d*) *All-out Level Flight.*

Mixture control as before for (*c*).

Throttle valves as far open as boost control will permit for maximum all-out level conditions.

Main and power jets in action as for " climbing."

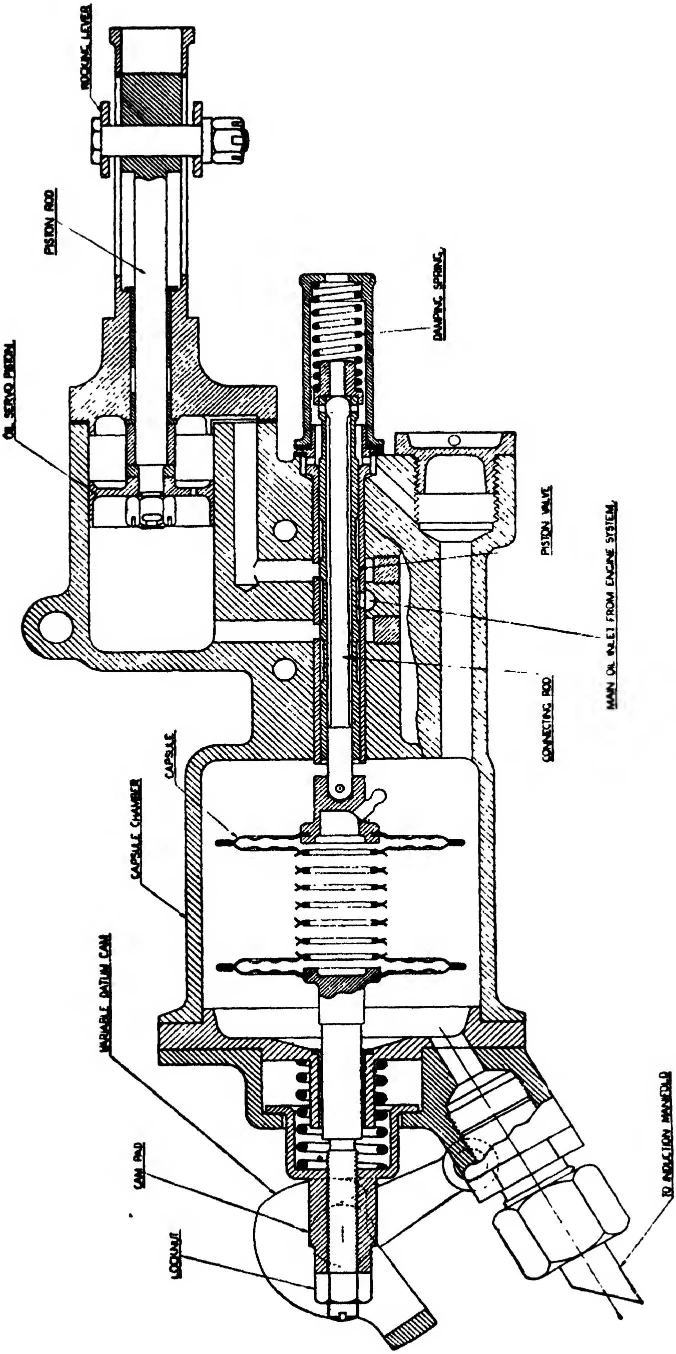
(*e*) *Cruising.*

Throttle set to give cruising R.P.M.

Power jets out of action and series valve closed.

Main jets only in action.

Mixture control valves opened to admit extra air to main diffusers to weaken the mixture.



AUTOMATIC BOOST CONTROL

Fig. 19.

MAINTENANCE.

General Notes.—All oil holes in carburettor control shaft bearings should be lubricated regularly.

If carburettor floods and indications show that the float needle valve seats are worn these parts must be removed. It is inadvisable to try to restore them by lapping together again.

It is advisable from time to time to remove the jets and, if possible, the slow-running tubes, turn on the fuel supply and flush out any sediment or water which may have accumulated in the passages.

Clean the jets and replace, taking care that the fibre washers are fitted under the jet heads and that the locking wire is replaced.

After lengthy service it is also advisable to check the calibration of the jets.

When the carburettor is dismantled, for overhaul, lightly smear the faces of the mixture control valves with graphite grease before re-fitting.

Automatic Boost Control.—This comprises a control unit and a system of linkage connecting it to the hand and carburettor throttle.

The Control Unit, Fig. 19, comprises an aneroid capsule inside a chamber connected by a pipe to the induction manifold of the engine.

The capsule is mounted on a spindle at each end.

The outer spindle is threaded and fitted with a cam pad and lock nut.

The inner spindle operates a piston valve which controls a supply of high pressure oil from the engine to a servo piston, housed in a cylinder adjacent to the aneroid capsule chamber.

Oil is admitted to either side of the servo piston as governed by the piston valve. The latter in turn is governed by the expansion or contraction of the capsule, which is affected by the pressure from the induction manifold. The cam pad for the aneroid capsule and the outer spindle is free to move in and out of a guide on the capsule chamber, and is operated by a special cam connected to the throttle pick-up lever. This is known as the Variable Datum control, and provides direct hand control over the boost pressure at any height up to maximum power altitude, when the throttle is full open to give rated boost at maximum R.P.M. (5 mins. only).

The aneroid capsule, however, maintains a constant boost pressure at any particular hand throttle setting irrespective of change in altitude below maximum power altitude. To enable maximum permissible boost to be obtained for take-off, a lever, operated by the cam on the enrichment jet control on the carburettor, forces the variable datum cam and pad further inward beyond the rated boost position, and so delays the reversing action of the valve until the maximum boost pressure position of the carburettor throttle is reached.

The Control Linkage System (Fig. 20).—The throttle pick-up lever is connected directly to the variable datum cam, and its other extremity is connected to a rocking lever, which is fulcrumed at the outer end of the servo piston rod of the boost control, mentioned above. The opposite end of the rocking lever is connected directly to the carburettor butterfly throttle lever.

Therefore, whatever the hand throttle setting may be, this end of the rocking lever becomes the fulcrum, and the other end connected to the carburettor throttle is affected only by the boost control unit.

Subsidiary linkage from the throttle pick-up shaft operates the power jet and accelerator pump.

Owing to the Dagger III. engine being rated at a low altitude, full throttle can be used with safety for taking off at sea level.

Graduated quadrants are fitted to the throttle and mixture pick-up levers for convenience in coupling up to the aeroplane controls.

Boost Override.—A separate system of linkage interconnects the mixture control, the boost overriding lever, and the enrichment jet, and is arranged that, while operating the mixture control from " weak " to " normal rich," a cam action of the linkage ensures that no movement of the boost override lever and enrichment jet valve can take place.

Only beyond the " normal rich " position does the cam bring these into operation, and a toggle action on the mixture control cock lever ensures that the latter remains closed during this operation.

Mixture Control.—This is operated by hand and provides not only control of mixture strength between " weak " and " normal rich," but beyond the " normal rich " position it operates the levers and valve controlling the boost override and enrichment jet.

NOTE.—Since there is no interlocking linkage between the throttle and mixture controls on the engine, provision must be made on the cockpit controls for the mixture control to be returned automatically to the " normal rich " position when the throttle is closed.

The cockpit controls are to be adjusted to give the required movement of the throttle pick-up lever on the engine so that all corrections of the boost pressure must be made by means of the adjustments provided on the cam pad of the boost control unit and the engine linkage. (See below).

Adjustments—Rated Boost Pressure.—Should the engine exceed or fail to attain rated boost at full throttle, with the variable datum cam at the top of its lift, then it is necessary to adjust the setting of the aneroid capsule by slackening the locknut and adjusting the spindle by means of a screwdriver, meanwhile holding the cam pad with a spanner.

To increase the boost pressure, screw the spindle in, and vice versa. (See Fig. 19).

Maximum Permissible Boost Pressure.—Adjustment of this is obtained as follows. Set the throttle lever to the " slow running " position, and the mixture control to the " normal rich " position. First adjust the fulcrum at "A" (Fig. 20) along the serrated link as required, slacken the adjustment of the connecting link " B " and reset so that the variable datum cam is just making contact with the cam pad (Fig. 19). Lock the adjustment. A check test for boost pressures should be made with the engine running, and any further adjustments should be made to the foregoing procedure. This method gives adjustment of the cam axis, and therefore of the lift required for M.P.B. without altering the original rated boost setting.

"A" is moved towards the carburettor to increase M.P.B. and vice versa.

Lubrication System (Figs. 21, 22 and 23.)—**General.**—The lubrication system of the "Dagger" Series III. engine is of the conventional dry sump type in which there is a constant circulation of oil through the engine from and back to an external oil supply tank, oil being delivered to the pressure system by a single stage pump.

The scavenge system uses the lower portion of the bottom half of the crankcase as a sump, the front and rear ends of which are scavenged by two separate pumps. The pumps are embodied together in a large unit at the bottom of the timing casing. The Tecalemit pressure filter, the two scavenge filters, the relief and reducing valves, and the supercharger metering pump are also incorporated in the main pump unit.

The Main Pump Unit—Pressure Pump and Circuit (See Fig. 23).—This takes oil from the tank through a coarse gauze filter in the inlet port, and delivers it to the chamber in which the Tecalemit filter is located.

This filter comprises a double felt element fitted with a central tube. Oil passes through the felt from the outside to the central tube, whence it travels through cored passages to the main feed pipe to the engine.

The pressure filter chamber incorporates a spring-loaded by-pass valve to relieve high pressures in the chamber due to cold oil.

A cored passage leads oil from the main delivery passage to the high-pressure relief valve and the pressure reducing valve. The overflow from the high-pressure relief valve is delivered back into the inlet side of the pressure pump. For adjustment of the relief valve, see page 233.

The reducing valve, the construction of which is described in page 233, delivers low pressure oil into a passage in the pump body leading to the timing casing.

A system of oil ducts in the walls of the timing casing and certain oil pipes ensures the lubrication of the timing gear and accessory drives supercharger driving gears, camshafts and rockers. See Figs. 21 and 22, and page 246.

A low-pressure feed is also led through drilled passages in the pump casing to the supercharger metering pump.

The Scavenge Pump Circuit (Fig. 23).—The scavenge oil from the forward end of the crankcase enters the pump through a passage in the timing casing, which leads through a port in the upper face of the pump casing. The oil proceeds via cored passages to the innermost of the two concentric gauze strainers. It passes through the gauze to the space between this and the inner filter casing, through a ring of holes at the bottom of the central tube. It then passes upwards and through cored passages to one pair of scavenge pump gears and is delivered into the pump casing.

The scavenge oil from the rear end of the crankcase and front scavenge pump falls into the bottom of the pump casing, whence it is drawn past the pump casing drain valve and through a cored passage to the inside of the outer gauze strainer. After passing through the gauze it is conducted through further cored passages to the other pair of scavenge pump gears, and outlet port. The pump casing drain valve prevents loss of oil from the inside of the casing when the scavenge filters are withdrawn.

The Engine Pressure System (Figs. 21 and 22.)—The oil delivered at the high-pressure outlet port on the oil pump, passes through a short pipe to the underside of the crankcase and so through a passage therein

to the main oil gallery which runs the entire length of the lower half of the crankcase.

Branch pipes are led from the gallery to unions on the crankcase cross webs, and drilled passages, leading from these, conduct oil to the crankshaft main bearings. A duct from the forward end of the gallery leads oil to the airscrew shaft rear bearing, and extends through the front cover to the magneto intermediate driving shaft and cross-shaft.

The foremost bearings of the two crankshafts are lubricated by means of two pipes leading from unions in the forward wall of the crankcase which are fed from the main oil gallery.

These feeds are each connected by a drilled passage to an oil jet directed on to the reduction gears. The oil feed to the crankshaft main bearings passes through transfer holes to the inside of the crankshaft, whence it passes through transfer holes in the webs and crankpins to the connecting rod big end bearings. Oil transfer holes in the forked connecting rod bearing shells ensure a supply of oil to the plain rod big ends. The plain small end bushes are supplied with oil by means of passages drilled through the rod from the big end.

The low pressure feed from the reducing valve is led by passages drilled in the timing casing to the camshaft intermediate driving shafts, timing gear driving shaft bearing, starter driving shaft and generator driving shaft, timing gear intermediate shaft, oil pump idler, and fuel pump drive bearings.

Two branch pipes lead oil from the camshaft intermediate driving shaft bearings to the camshaft inner driving shaft bearings, and a duct from the main low pressure passage in the timing casing feeds the L.H. side bearing of the auxiliary drive cross shaft. The latter is hollow, and transfers the oil across to the two bearings for this shaft on the R.H. side of the timing gear casing. A duct from the outermost of these two bearings leads vertically downwards to a horizontal passage which feeds the fuel pump drive and the fuel pump itself.

The main low pressure passage also feeds external oil pipes leading to the upper and lower camshaft casings.

The oil feed to each casing travels through drilled passages to the camshaft outer drive shaft bearings and rocker spindles. These are hollow, and in addition to supporting the rockers they act as oil galleries, leading oil to the camshaft bearings below them by oil holes drilled in the spindles and bearing housings. The oil feed to the rocker bearings is also led by passages drilled in each rocker to the self-adjusting tappets.

The timing casing is fitted with an oil pipe, leading from a face fed from the main low pressure oil passage, to a banjo union on the supercharger casing.

The latter is provided with drilled passages leading to the rear bearings of the two supercharger layshafts. The latter are plugged and provided with oil ports arranged in such a manner that a reduced feed is given to the gear teeth and supercharger drive clutch bearings, and also the forward roller bearing of the plain layshaft, while the main feed passes up the centre of the plug in the clutch layshaft to the front bearing, whence it feeds the differential shaft of the supercharger drive, through a passage in the housing.

The differential shaft is plugged with a duralumin liner, and oil holes are drilled in the shaft to lead oil to the differential shaft bearings, and the gears and their bearings.

The supercharger spindle front bearing is lubricated by oil mist drawn through from the drive casing by the suction of the supercharger. Excess oil drains out of the bearing through a hole in the housing, for which a breather is provided. The rear bearing is lubricated by means of the small metering pump mentioned previously, which delivered a small quantity of oil to the bearing housing.

A pipe line from the pressure filter delivers high-pressure oil to the automatic boost controls.

The Splash System.—The pistons and cylinder bores are lubricated by splash oil from the crankshaft main and connecting rod big end bearings.

Oil from the reduction gear jets and magneto drive bearings is splashed over the gears of these drives, and also lubricates the airscrew thrust bearing. A small quantity collecting in a well in the front cover lubricates the distributor intermediate shaft-bearing.

Oil leaking from the rocker spindles, camshaft bearings, and tappets is splashed over the bevel gears, cam faces and valve stems. Similarly, with the timing casing and supercharger drive, the oil escaping from the various pressure fed bearings is well distributed over the gears in the timing and supercharger drive casings.

The Scavenge System (Fig. 23).—The oil in the camshaft casings of the upper cylinders drains down the camshaft drive shaft housings at the rear end and also down drain pipes at the forward end, and so into the crankcase. The oil in the lower camshaft casings is scavenged by small vane pumps at each end of the casings, which return the oil to the crankcase and timing gear casing. These pumps each have a small gauze strainer located on the suction side in the casing cover plate, under a diamond shaped flange.

The overflow from the automatic boost control is returned to the oil pump casing. All splash oil in the crankcase and front cover drains to the bottom of the crankcase, and all that in the supercharger drive housing and timing gear casing drains into the oil pump casing.

The scavenge oil at the forward end of the crankcase collects in a pocket, whence it is drawn by the upper scavenge pump through a long tube and a passage to the timing gear casing, and through the inner scavenge strainer. The upper scavenge pump delivers the oil into the pump casing.

It will be observed that all the splash and scavenge oil in the engine is returned into the pump casing. It is drawn from here by the lower or main scavenge pump through the outer scavenge strainer and is delivered to the oil outlet connection.

INSTALLATION.

Unpacking.—The case consists of an outer shell housing a heavy wooden engine stand bolted to the base. The sides are joined permanently in a unit from which the lid and base are detachable. The lid is held to the sides by 8 bolts through eye plates, and the sides are provided with wooden lifting handles and battens upon which are mounted steel straps fitted with lifting rings at their upper ends. The base is fitted with two wooden runners and two steel cross straps turned up at their outer ends. The lower ends of the side straps fit inside these and are secured by one large bolt through each strap.

A tinplate lining and lime pot for absorbing moisture are provided for cases for shipment abroad. The engine stand is secured to the base by 8 bolts through the bottom members, and the engine is fitted with special feet bolted to the upper members by two bolts per foot.

To unpack a standard case, remove the four lower bolts and lift the shell off vertically. A crane with a lift of at least 15 feet is necessary to hoist the shell and chain slings clear of the engine.

If required as a stand apart from the case, the engine stand can be detached by undoing the 8 nuts which hold it to the base, and lifting the engine and stand.

To open a tin-lined case, remove the 8 bolts securing the lid to the shell and the lid. Unsolder the top surface of the tin lining. Remove the cross struts over the ends of the engine stand, and lift the engine and stand out of the case as previously described. Set the engine and stand down on to a dry, level floor.

Preparation for Installation.—The engine should be examined externally for damage which may have occurred in transit. Remove the airscrew hub, and any components which may be packed separately on the base of the case.

The engine and accessories should be wiped clean from grease, anti-corrosion fluid, and foreign matter.

All aeroplane pipes must be thoroughly flushed with petrol and, if possible, blown through with compressed air. Remove all union blanks and examine the unions and pipe nipples to see that these are perfectly clean and bed accurately in one another to give tight joints. If they do not, they must be lapped together with fine grinding paste. Wipe clean and replace blanks. Damage to the special lining of certain types of flexible pipe must be avoided when assembling unions.

With gravity feed, the flow of fuel through the main feed pipe should be checked at the engine connection end, and must be 14½ pints per minute minimum, as tested by means of a calibrated vessel and stop watch. Should the required flow not be attained, examine the pipe lines for air locks, foreign matter, acute bends, choked filters, and inadequate tank vents.

Examine the engine mounting joints for security, and the structure for rigidity and alignment. Any slackness here will cause vibration in the aircraft when the engine is running.

Test the flexible shaft to the tachometer for ease of rotation by turning the shaft and instrument by hand from the engine end. If it is difficult to do this, and examination of the shaft is desired, it should be uncoupled

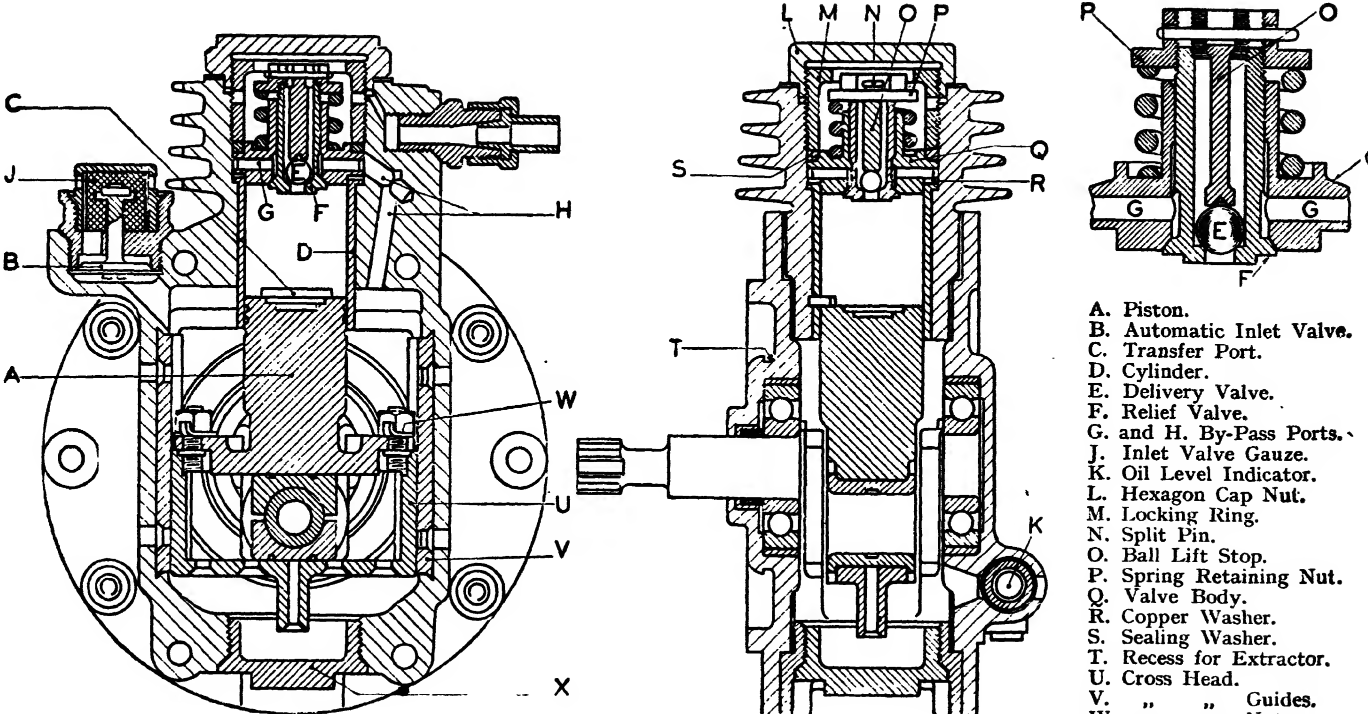


Fig. 24.—Air Compressor (B.T.H.).

A. Piston.
B. Automatic Inlet Valve.
C. Transfer Port.
D. Cylinder.
E. Delivery Valve.
F. Relief Valve.
G. and H. By-Pass Ports.
J. Inlet Valve Gauze.
K. Oil Level Indicator.
L. Hexagon Cap Nut.
M. Locking Ring.
N. Split Pin.
O. Ball Lift Stop.
P. Spring Retaining Nut.
Q. Valve Body.
R. Copper Washer.
S. Sealing Washer.
T. Recess for Extractor.
U. Cross Head.
V. „ „ Guides.
W. „ „ Nuts.
X. Base Plug.

and withdrawn from the casing by lifting out the slotted collar from one end. Acute bends may also be the cause. No bend should have less than a 9-inch radius.

Keep the shaft and its ends well greased, and take care not to kink the former when replacing into the outer cover. The above test should always be made.

Check the oil level in the air compressor crankcase by depressing the plunger of the oil indicator on the side of the crankcase. (Fig. 24). If no oil appears, the crankcase can be replenished by first removing the gauze cover of the air inlet valve, depressing the latter, and pouring in the required quantity of D.T.D. 72 (castor) oil. Mineral oil is not used. Check the level again as before. This should not be exceeded on any account. Check the tightness of all external nuts, unions, and locking devices.

Installation of Engine.—Remove the 12 nuts holding the engine to the stand, screw the detachable lifting eye on to the airscrew shaft, and attach the approved sling.

Hoist the engine to a convenient height, and remove the dummy engine feet. Ensure that the crankcase feet faces are clean and free from burrs, and assemble the aircraft engine feet to the crankcase.

Lower the engine carefully into position in the mounting so that the engine feet engage with their corresponding fittings on the mounting. These must be bolted up dead tight, and locked. Care must be taken not to damage ignition wires, pipes and other engine fittings against the mounting when lowering.

When installing, care must be taken to ensure that the engine feet and mounting are correctly aligned by packing pieces or other suitable means to ensure that the load will be distributed equally on all the feet.

Set the cockpit throttle lever at the " full throttle " position on the quadrant, and fix the carburettor pick-up lever at the " full throttle " position on the carburettor quadrant. Adjust the connecting linkwork for length, couple this up, and lock the adjustment. Connect the mixture control similarly.

Test the controls for smooth and steady action, freedom from backlash and looseness, full travels, binding at any point, and fouling of any part of the installation. These controls should be stiff enough to prevent throttle " creep " when the engine is running, but not so stiff that undue stress will be put on them when operating.

Check the mechanical and regular functioning of the interconnecting device between the throttle and mixture controls and re-adjust if necessary. Connect the slow-running cut-off control.

Remove all union and pump connection blanks, prime all oil pipes, and connect up. All air must be driven out of the fuel and oil systems before finally tightening up unions. Care must be taken not to twist metal pipes when tightening up unions, and also that the joint washers of flange connections are not defective. All joints must be tight, particularly those in the main oil feed pipe, or low and fluctuating oil pressures will result. Filter caps must be tight and locked.

Connections.—Check the connection over to the following list :—

Oil.—Inlet from main tank, outlet from pump. Inlet to carburettor, outlet from supercharger jacket to main tank. Oil tank vent pipe to engine. Inlet and outlet thermometers, pressure gauge connections,

(transmitting type), lower L.H. camshaft casing (low pressure), and pressure filter housing (high pressure).

Fuel.—Main feed to fuel pump. Delivery from fuel pump. Inlet to carburettor. Drain from fuel pump. Pressure gauge connection. Petrol priming connection.

Miscellaneous.—Boost gauge connection, engine speed indicator drive shaft. Clutch bell-crank connection on Inertia Starter. Starter handle and shaft. Electric cables to generator. Magneto earthing wires. Hand magneto (or coil) to engine distributors. Gun gear drain. Air compressor connection. Venturi drain connection. Connections to cylinder temperature indicator.

Ensure that the control operating the starter clutch bell-crank is operating easily and without hindering the action of the clutch throw-out. Check the starting handle and shaft for ease of operation. (Fig. 25).

Test the leads from the magnetos to the cockpit switches, those from the distributors to the hand magneto, and those from the generator to the aeroplane electrical system, with a hand lamp. Ensure the correct connection of the magnetos to the corresponding magneto switches. Leave the ignition switches in the " off " position.

Remove the air intake blanks and fit the air intake pipe. Remove the exhaust port blanks and fit the exhaust manifolds with joint washers at all the cylinder head flanges.

The engine air chutes and outer cowling are to be fitted up for trial to ensure that this assembly is rigid and secure, all panel attachment fittings are in order, and that the cowling does not drum or rattle.

Airscrew and Hub.—When fitting new wooden airscrews, ensure that the bore and bolt holes are a clearance fit on their corresponding hub components.

Fit the airscrew and front flange to the hub, ensuring engagement of the flats on the bolt heads with the ridge on the rear side of the hub flange, and that the spigoted rear faces of the nuts enter the front flange holes, when assembling. Tighten the nuts hard and evenly from opposite sides of a diameter, ensuring that the hub flanges bed evenly on to the airscrew. Check the airscrew unit for balance, pitch, and track, to the usual Air Ministry procedure and, if correct, lock up the nuts with tab washers,

Assembly to Airscrew Shaft.—Clean the fitting parts of the hub and airscrew shaft, smear a thin film of tallow and white lead on the shaft splines, hub nut threads, and the collet and cone. Fit the flat washer and collet to the shaft, and follow with the airscrew and hub assembly, pushing this well home on the shaft.

Assemble the front cone to the hub nut and fit to the shaft, finally tightening the spanner with sufficient blows with a 4-lb. hide hammer on the spanner until all movement ceases.

A locking plate engaging with pegs on the front flange is supplied.

Having fitted the airscrew and spinner to the shaft, check the clearance between the rear end of the spinner and the engine cowling. If necessary, remove the airscrew, spinner, and cowling panels and make any alterations required. Afterwards carry out the final inspection.

A plate giving general running instructions is provided with each engine, and should be fitted in a prominent position in the cockpit. The data thereon must be adhered to as closely as possible.

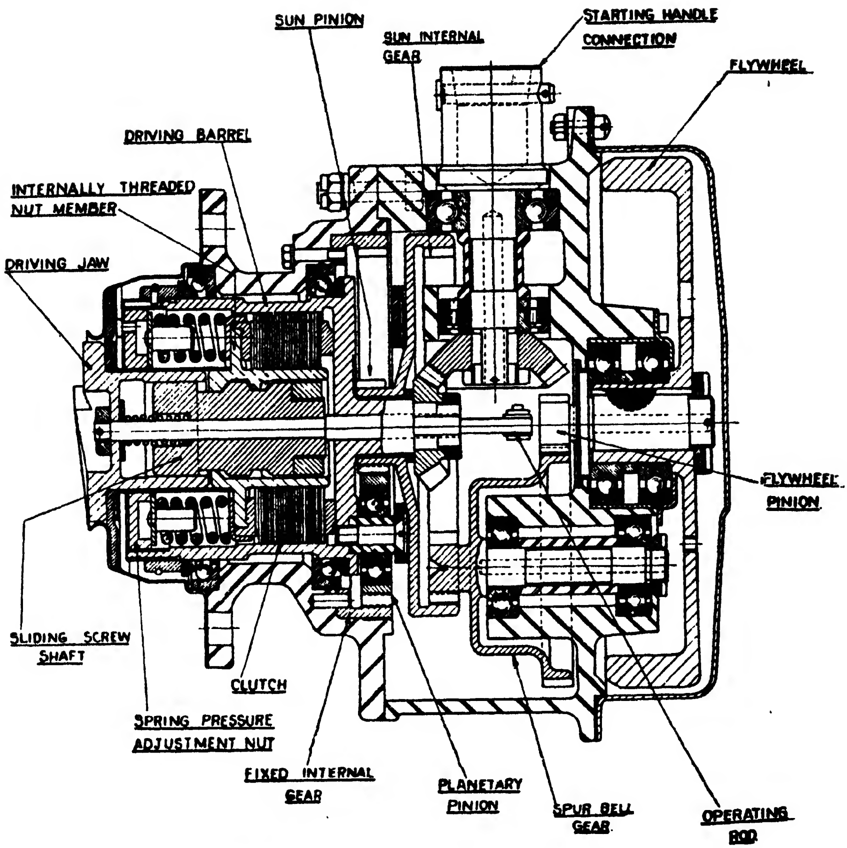


Fig. 25.--Arrangement of Inertia Starter.

RUNNING NOTES.

Inspection before initial Ground Test.

(1) Remove all outer cowling.

(2) Check the engine controls to see if, on completion of installation, the conditions previously mentioned still apply.

(3) Check and, if necessary, adjust the make-and-break contacts. Wipe the interior of the distributors with a petrol-damped rag, and dry off. Replace the distributors and make-and-break covers.

(4) Carry out magneto lubrication instructions given in Maintenance Schedule (40 hours).

(5) Remove all dummy sparking plugs, drain all cylinders, and swing the engine three or four times to ensure that all is clear. Smear a trace of graphite grease on to the threads of a clean set of sparking plugs, and fit tightly into the cylinders. Fit and secure ignition wires and screens.

(6) Fit the airscrew and hub to the shaft if it has been necessary to remove this for alteration to the cowling.

(7) Clean the oil and fuel filters. See that all filter caps are refitted securely. Fill up the fuel and oil tanks, using fuel and oil to the correct specifications. Secure the filter caps, and ensure that the tank vents are clear. Examine all fuel and oil pipe connections in the installation for leakage.

NOTE.—It is unnecessary to fill the oil tank full for initial test purposes, as the oil is drained out afterwards. A quarter to a third of a tank full should be ample.

(8) Inspect engine air chute for security.

(9) Do not fit outer cowling panels until after a short test run.

(10) Remove all loose tools and rag from the engine and aircraft.

(11) Remove blanking plug from union on the cover plate at the R.H. end of the Tecalemit filter housing. Connect a hand oil pump and prime the engine with warm, clean D.T.D. 109 oil (12 pints) or until front hydraulic tappet cannot be pushed down. Replace the union blanking nut and lock with wire. Also detach the top union of the feed pipe to the supercharger rear bearing and loosen the union on the lower end. Prime the pipe until oil issues from the loosened union and then tighten both unions.

Starting.

(1) See that the main magnetos are switched off, the throttle is closed, and the oil cock is turned on. Prime the carburettor float chamber by turning the fuel cock to gravity, or if no gravity tank is fitted, by hand pump. Open the main fuel cock (main tank to fuel pump) so that the fuel pump will commence to deliver as soon as the engine starts.

(2) Insert the starting handle in to the starter " dog " on the L.H. side of the engine bay.

(3) Set the throttle about $\frac{1}{8}''$ open from the " slow-running " position in the cockpit quadrant (*i.e.* to give 700-800 R.P.M.) set the mixture control to " normal rich " position (Rated Boost).

(4) Wind the handle of the Inertia Starter, gently at first, to overcome

the initial inertia, and then with increasing effort, until handle speed of 70-80 R.P.M. is obtained.

(5) Prime as required (see below) and switch on the main and hand magnetos.

(6) Withdraw the starting handle and engage the starter clutch, at the same time winding the hand magneto briskly.

(7) An immediate start should be obtained. Should the engine fail to start, rewind the inertia starter, if run down, and repeat the procedure given above, preferably without priming again. Switch off the hand magneto when the engine has started.

Priming.—Do not prime excessively, particularly with a hot engine, and/or in hot weather, one stroke of the priming pump usually being found sufficient for a hot engine. It is necessary, however, to prime more heavily in cold weather and, should very cold conditions obtain, an extra stroke should be given as the engine starts.

Three full strokes of the above pump, and one stroke with the throttle lever (operating the accelerator pump) will be found sufficient for a cold engine in normal weather conditions. It is better to prime insufficiently than excessively. The amount necessary for starting varies with the heat of engine and conditions of weather. A greater amount is required on a cold day than on a hot one.

Always turn off the primer after use.

Ground Test. (New Installations only).—Having started the engine from cold, keep the engine speed below 900 R.P.M. and watch the oil pressure gauge until a settled pressure is registered and circulation of oil is well started. If the oil pressure fails to register, switch off the engine and investigate the cause.

Having obtained satisfactory oil pressure, open the throttle until the engine is running at 1300-1400 R.P.M. A slight period of vibration or gear noise may be experienced between 950 and 1150 R.P.M. and the engine should be accelerated quickly from 900 to 1300 R.P.M. to avoid this. This speed should be maintained until the inlet oil temperature is at least +20°C. before proceeding further. Close throttle to idling speed and turn fuel distributor cock from " normal system " to " alternative system." Test again at 1300-1400 R.P.M. Close throttle and return fuel cock to " normal system." Allow the engine to idle for several seconds to ensure satisfactory oil and fuel circulation. Having run for a short time at low speed stop the engine and inspect for oil and fuel leaks, etc. Fit the cowling panels ready for a complete ground test, start the engine and continue as follows :—

Having obtained steady running with settled oil temperatures and pressures, the engine should now be accelerated 150 R.P.M. or so at a time, holding the speed steady at each stage for about 10-20 seconds, until the full throttle (Rated Boost) is reached.

While accelerating, special attention should be given to engine vibration, which should be barely evident at any speed. If vibration is excessive, the engine must be shut down at once, and the cause investigated. Under no circumstances should flight be attempted until the trouble has been rectified. If there is any tendency for the oil pressure to fall below 35 lbs. sq. in., the joints in the oil system should be examined for possible air leaks, and corrected.

While opening up, test the ignition system at say 1,500 and 2,700 R.P.M. as follows, and note engine speeds and smoothness of running. (Fig. 15).

(1) All switches on.
(2) L.M.E. and R.M.E. off. Others on.
(3) L.M.I. and R.M.I. off. Others on.
(4) Uncouple switch interconnecting bars.
(5) L.M.E. only off.
(6) R.M.E. only off.
(7) L.M.I. only off.
(8) R.M.I. only off.

The drop in engine R.P.M. during these tests should approximate the figures in the table below.

Tests (2) and (3) at	-	1,500 R.P.M. drop 150 R.P.M. 2,700 R.P.M. drop 75-100 R.P.M.
Tests 5, 6, 7 and 8	-	1,500 R.P.M. drop 50 R.P.M. 2,700 R.P.M. drop 30-40 R.P.M.

Should these figures be exceeded, or rough running be experienced, and the behaviour of the engine during test (2) be very different from that during test (3), an ignition fault may be suspected, and, if present, will be found during tests (5) to (8).

If during tests (5) to (8) it is found that half the engine cuts out, or an appreciable drop in R.P.M. occurs, it may be concluded that the fault lies in one half of a magneto or in its distributor wires or plugs. For instance, if half the engine cuts out at test (6) then it is clear that the R.M.I. circuit is at fault, for, were the R.M.I. circuit functioning properly, there would be at least one plug sparking in each cylinder of the right hand half of the engine, and hence that half could not cut out. Similarly, even though this half of the engine does not cut out entirely, but a considerable drop in R.P.M. or roughness of running occurs, then the fault, by similar argument, must be in the R.M.I. circuit. Faults in the other circuits will be found by similar procedure.

NOTE.—It is very undesirable to switch off a complete magneto at a time, thus cutting out half the engine, as considerable damage due to vibration is liable to occur. Should this condition be encountered as a result of legitimate testing, it must be accepted, but it should never be sought deliberately. (See page 235).

Note the instrument readings at full throttle (Rated Boost).

It must be noted that, with the variable datum Boost Control, full throttle position in the cockpit should give rated boost at the boost gauge. If not, an investigation should be made before commencing to re-adjust the boost control. Check the boost gauge, revolution indicator and other relevant engine instruments first. (See also page 244).

Steadily return the throttle to the idling position, repeating the test on independent ignition at 2700 and 1500 R.P.M., this time operating the switches in pairs, *i.e.*, both inlet or both exhaust switches as required. Further to the previous notes in connection with this, it is very important when operating the ignition switches in pairs to use ***both*** " Inlet " and ***both*** " Exhaust " switches together only.

The performance at maximum permissible boost (M.P.B.) must now be checked.

Move the mixture control lever to the " Override rich " position, and open the throttle steadily to the fully open position for a momentary burst at M.P.B.

Note the engine speed, boost pressure, oil and fuel pressures, and steadiness of boost control and running of the engine. Should adjustment of the maximum permissible boost setting be required, see page 244.

Steadily return the throttle lever to the " idling " position.

The engine should now be accelerated quickly to full throttle (ground speed) three times, and the average time taken in attaining this speed should be 3-4 seconds.

The engine should pick up speed at once and accelerate smoothly and without sign of " flat spot," and, also, it should idle at 500 R.P.M. without running roughly or " hunting."

Full throttle (M.P.B.) should not be prolonged beyond 10 seconds, nor should the engine be violently accelerated or decelerated except during specified tests of this nature. Return the mixture control to the " normal rich " position. After the initial ground test, it is advisable to shut down and make a general examination.

Stopping.—Throttle down to idling speed. Allow engine to cool down a little, operate cut-off control and switch off ignition. Care should be taken to avoid moving the airscrew while the engine is hot, or physical injury may be received in the event of a kick back.

When the engine has cooled, examine the cowling, exhaust manifold, tail pipes and fittings, airscrew, and general condition. Remove detachable cowling panels, and check over the engine installation for fuel and oil leaks, tightness of joints, connections, and nuts.

Check the engine mounting and fittings for security and general condition. Examine the airscrew and hub for tightness and security, the former on the hub and the latter on the shaft. Tighten if necessary and fit the locking plate to the hub nut. Fit the spinner. The oil system should be drained, fuel and oil filters cleaned, the oil system primed, and the tank refilled with fresh oil. All unions and filter caps must be tight. Replace cowling.

Ground Test in Service.—The foregoing procedure need only be observed for the first test after installation, while the following should suffice for everyday service.

(1) Start engine in accordance with procedure in pages 255 and 256.

(2) Run up to 1200-1400 R.P.M. (as in page 256, omitting the stop for inspection).

(3) All being satisfactory, open the throttle steadily to the fully open position (Mixture control at the " normal rich " position). While opening up, test the ignition system at 1,500 and 2,700 R.P.M. as indicated at tests (1) (2) and (3) of page 257, unless a fault be indicated or suspected, in which case run through the whole series of tests, indicated in that para. On reaching the full throttle (Rated Boost) position, open the mixture control to the " override rich " position and check the ground speed, boost pressure, and oil pressure. The engine should not be run at this setting for more than 10 seconds.

(4) Close the throttle to idling speed and give one smart acceleration.

Return the mixture control to "normal rich" and idle until ready for taking off.

Note that new or recently overhauled engines should receive more careful treatment than usual while running up. The engine should not be idled for more than 5 minutes without running up again to about 1500 R.P.M. before flight, to clear the engine of surplus mixture in the induction system.

FLIGHT NOTES.

Operation of Controls.—The following summarises the operations of note when using "Dagger" Series III. Engines fitted with hand mixture control and automatic boost control with override and enriching devices.

(1) *TAKE-OFF AND CLIMB.*

(*a*) Mixture control in "Override rich" position. (Enrichment jet open. Boost control setting now at M.P.B.) Throttle lever at "full throttle" position.

(*b*) When a height of 1000 feet is reached, the mixture control must be returned to the "Normal rich" position and the normal climbing boost restored, in which position the climb will be continued.

(2) *LEVEL FLIGHT (FULL SPEED).*

Mixture control to be in the "Normal rich" position. (Enrichment jet closed. Boost control setting now at rated boost).

Throttle lever at "full throttle" position.

NOTE.—Full throttle running at maximum speed must not exceed 5 minutes except in case of real emergency. Above full throttle height, mixture control can be applied to prevent R.P.M. falling.

(3) *CRUISING (Continuous Max. Boost*+$1\frac{1}{4}$ *lb. sq. in.)* Set throttle control to give required cruising R.P.M. and boost. Open mixture control towards the "weak" position until engine R.P.M. cease to increase and return towards "normal rich" position until R.P.M. just commence to fall.

Throttle back to give original cruising R.P.M.

(4) *CRUISING. (Economical, Max. boost* + $\frac{1}{4}$ *lb. sq. in.)*

Set throttle and mixture control as above. Then move mixture until R.P.M. fall by $1\frac{1}{2}$% of the cruising R.P.M. (*i.e.* 50 R.P.M.) and, without altering position of mixture control, open throttle to obtain original cruising R.P.M.

NOTE.—Under no circumstances must economical mixture strength ($1\frac{1}{2}$% drop in R.P.M.) be used to engine speeds in excess of max. cruising R.P.M. (*i.e.* 3500) and boost pressure must not exceed + $\frac{1}{4}$ lb. sq. inch after drop in R.P.M. has been regained by opening throttle. Aircraft must be flown in level, steady flight during these operations. If altitude is changed appreciably, that is by more than 500 feet, return mixture control to normal and repeat above procedure.

Cylinder temperatures of 270°C. must not be exceeded at any time.

In level flight at cruising speed, the cylinder temperatures should be about 210°C. and at full throttle on a steep climb 270°C. should not be exceeded.

When descending from high altitudes with the engine idling, the throttle should be opened occasionally to prevent the engine being overcooled and the plugs fouled.

The engine should attain 3975 to 4000 R.P.M. in level flight at full throttle at maximum rated boost altitude. This speed is only permitted for periods of not more than 5 minutes. Normal speed must not be exceeded for continuous flying.

Cold Weather Notes.—In cold weather, before flight, the necessary precautions for ensuring an adequate supply of hot oil to the engine must be taken. Unless this is done, not only will the oil pump be sluggish in starting the oil circulation when the engine starts, but the oil will probably be sufficiently viscous to cause damage to certain components due to high pressure when the engine is accelerated.

POSSIBLE ENGINE TROUBLES AND REMEDIES.

Failure to Start.—The customary sources are to be investigated in this case. Ensure that the priming jet is clear.

(1) Oil pressure low, fluctuating or failing to register at all, due to—

(*a*) Faulty gauge—check against standard instrument.
(*b*) Air leaks in joints of suction pipe from tank to pump. Examine pipe joints.
(*c*) Sticking relief and pressure reducing valves. Remove the relief valve without disturbing the spring adjustment and clean the valve and body thoroughly. Remove and clean the pressure reducing valve. Retest the engine and should the pressure still be unsatisfactory, remove and test the relief valve spring for load.
(*d*) Should the condition of the relief valve spring be satisfactory, the cause may be excessive crankshaft bearing or pump gear clearance, or a faulty oil feed gallery. In this case, no amount of relief valve adjustment will either disclose or cure the trouble.

The following course should be taken :—

(1) The existing pump unit should be changed for one which has been proved satisfactory on a rig. If, after testing again, the oil pressure is still unsatisfactory, the pump unit, *i.e.* gears, relief valve and filter cannot be the source of the trouble. Attention should then be directed to the main oil feed pipe from pump to crankcase, the oil gallery, main bearings, and big ends, which should be subjected to examination under pressure as follows :—Fit the engine to a rotatable stand, and invert it. Remove the two lower banks of cylinders (which will now be at the top) as in Top Overhaul Notes, sections 1 to 6.

(2) Disconnect the pipes from the crankcase to the reduction gear oil squirts and blank the unions. Connect a hand oil pump to the priming union on the R.H. end of the Tecalemit filter chamber. Use clean D.T.D. 109 oil at a temperature of not less than 20°C. (68°F.)

(3) Disconnect the oil inlet pipe to the pump and blank the flange.

(4) Remove the end cover of the reducing valve chamber and the valve. Fit the special plug to cut off the low pressure system for the purpose of this test only.

IMPORTANT.—This test plug must be removed and the reducing valve and cover plate replaced before attempting to start the engine.

(5) Disconnect high pressure oil feed to auto boost control and blank the union or fit a pressure gauge at this point if there is not one already fitted on the hand oil pump.

(6) Ensure, by continuous pumping, that all air is driven out of the high-pressure system and that a steady pressure of about 40 lbs. sq. in. is being maintained. It should now be possible to locate the leak directly by inserting a small electric lamp into the crankcase cylinder apertures and inspecting the various bearings and the connections in the oil gallery feed pipes, before dismantling the engine. In the event of an excessive leak being discovered, a complete strip and rebuild must follow in which case it is permissible to re-adjust the relief valve if necessary to give the required oil pressure with the new conditions.

Misfiring. (Application of Magneto Checks).

(1) If misfiring is suspected or observed, the cause may be traced by applying the tests (page 257). The engine will run roughly or cut out intermittently when these tests are applied. Examine all H.T. cable terminals for satisfactory contact, commencing with the four feed cables between the magnetos and distributors. If these are satisfactory and all contacts are sound, remove the sparking plug screens and test. Ensure that all H.T. bushes in the magneto elbows and distributors are making satisfactory contact. Should a magneto be suspected, and no ready means of rectifying the trouble be apparent, the magneto in question must be changed.

Excessive Fall in Engine Speed (during Ignition Tests).

(1) Should the engine R.P.M. fall below the limits set in page 257 or the engine cut out altogether, using the switches as described in that paragraph, carefully check the switches and the wires from these to the magnetos and, if no cure is effected, change the magnetos.

Automatic Boost Control.

(1) Failure to obtain rated boost at full throttle (Normal rich) mixture.

(2) Failure to obtain maximum permissible boost (M.P.B.) at full throttle (Override-rich).

(3) A tendency for the boost control to " hunt " will be due probably to dirt on the piston valve.

Air Compressor.

(1) Failure to reach Set Pressure.—Check the oil level in the crankcase, and, if necessary, replenish to the instructions in page 251.

(2) Excessive Pressures Developed.—This shows that the main valve is inoperative, due to formation of carbon, and it is therefore necessary to dismantle and clean it. Before attempting to remove the compressor main valve (Fig. 24) the pressure in the air receiver must first be released.

Metering Pump (Supercharger).—In the event of any difficulty being experienced with the small metering oil pump supplying oil to the impeller spindle rear bearing, the pump must not be dismantled, but is to be returned to stores depot for adjustment by the makers, or to repair depot.

TOP OVERHAUL.

Periods of service permissible between top overhauls cannot be stated definitely, as they depend entirely upon operating conditions. The symtoms of need for top overhaul are generally overheating, loss of power, rising oil consumption, increasing tendency to knock, and general lowering of performance, and should this be concurrent with a period of long service, it will be evident that a top overhaul should be given.

The following notes cover the necessary operations for this. It is also strongly recommended that in spite of the fact that parts are numbered, suitable racks and labelled boxes should be provided in order to segregate similar parts, as an aid to ready identification and to avoid confusion.

All split pins, spring circlips, tabwashers and joint washers which have been disturbed must be renewed, as mentioned on page 267. All rag used for cleaning should be free from fluff and foreign matter.

Partial Dismantling.

(1) Remove the spinner and inner mounting. Remove the hub nut locking plate and unscrew the hub nut. Draw off the airscrew and hub, using extractor No. 41944. Remove cowling, air intake, and exhaust manifold.

(2) Detach the airchutes, remove engine from aircraft, and fit on to a rotatable stand. Remove the sparking plugs, and detach the ignition wires from their brackets, securing these out of the way.

(3) Remove the air deflector plates and oil pipes to the camshaft casings.

(4) Detach the locking wires from the induction pipe nuts, slacken off the latter. Slacken the nuts on the induction pipe glands on the crankcase with the special " C " spanner No. 81915, and remove the pipes without disturbing the joint rings.

(5) Remove the nuts holding the outer glands of the cover tubes for the camshaft driving shafts, and slacken the nuts on the inner glands. Slide the tubes into the inner glands.

(6) Slacken the nuts of the cylinder head studs as far as possible, and ease each camshaft casing and head unit clear of the studs. Remove the nuts, and lift the camshaft drive shaft from the housing, and the unit clear of the cylinders, taking care not to lose or damage the joint rings. Draw off the cylinders.

(7) Remove the circlips and retaining washers from the gudgeon pins, tap out the pins, and remove the pistons. Slide three pieces of thin steel strip under the rings of each piston, space them equally, and slide the rings over them. It is advisable to fit a cover plate, having a square hole cut in it, to receive the connecting rod, over each crankcase orifice. All gudgeon pin circlips must be discarded and new ones used whenever a gudgeon pin is refitted.

(8) Remove the camshaft casing covers and the caps securing the rocker shafts to the camshaft bearing housings, and lift the rocker units out. Leave the rockers on the spindles. Remove the oil drain pipe adaptors from the forward end faces of the top camshaft casing and the lozenge shaped cover plates from their rear ends and also from the underside of the bottom camshaft casing covers. Extract the gauze strainers. Early engines have only the lower strainers fitted.

(9) Using the tool No. 41772 depress the valve spring retainers, and remove the collets, using the tweezers No. 42101 provided, and the springs and valves.

Cleaning.—Scrape piston crowns and interiors free from carbon and clean out the oil holes. Carbon is not to be removed from the bottom of the grooves unless a new ring has to be fitted. The gudgeon pin bores in the pistons should not be touched unless really necessary as these are machined to a close limit. Scrape the cylinder heads, joint ring spigots and valve ports clear of carbon, taking care not to damage the valve seats in the process. Clean the joint rings. Polish all gudgeon pins and small end bushes free from discoloration, and clean up the connecting rod small ends. Polish the valve stems and heads and wipe the seating faces clean. Remove all carbon from the cylinder head ends of the barrels and clean the spigot faces.

Wipe the cowling, airchutes, and deflector plates clean from oil and foreign matter, and clean the hub assembly. Wash all parts thoroughly in paraffin, making sure that all traces of carbon, sludge, and oil are removed.

Examination.—For examination of the parts dismantled for top overhaul, a short list of fits and tolerances is included in an addendum at the end of these notes, when issued for service use.

Examine—Cowling, airchutes, and air deflectors and spinner for cracks, broken or defective spring buttons, and signs of movement or fretting. Exhaust manifolds for cracks, signs of burning out, cracked or broken flanges, and general condition. Airscrew-hub parts for fretting and wear, and the airscrew shaft for " stepped " splines or damaged nut threads. Sparking plug components and ignition wires for damage due to chafing or excessive heat, and screens for damaged insulation. Cylinder heads for cracks, broken fins, and general soundness, broken or stripped studs, loose camshaft casing ring nuts, etc.

Cylinders, cylinder head studs, nuts, joint rings, and all oil pipes and glands for general condition. Pistons for cracks and general soundness, signs of burning, worn or scored skirts, worn ring grooves, stepped or burred over lands, signs of " picking-up," scoring, or wear in gudgeon pin bores. Fit of piston rings in grooves (side float), wear and scoring of rings, partial discolouration denoting gas leakage, ring gaps when tested in cylinder square with bore.

Gudgeon pins, connecting rod bushes, and retaining washers for condition. Valves for distortion and burning of heads, cracked heads, or badly marked valve stem ends, worn or scored stems, worn collet grooves, fretted or cracked valve collets and spring retainers. Valve springs for cracked wire, and breakage. Damaged parts, and those which cannot be renovated conveniently, must be renewed.

REPAIRS.

Cracks in cowling and other sheet-metal work should, if possible, have a small hole drilled at the end, and a stiffening plate riveted in position across the crack. Cracked exhaust manifolds should be welded up whilst mounted securely on a jig in order to prevent distortion. The area of metal surrounding the weld must be normalised after welding. Steps in the splines of the airscrew shaft should be stoned down smooth, care being

taken to stone all the splines by the same amount. Clean up any signs of fretting or picking up on the airscrew hub components. If the threads on the airscrew shaft for the hub securing nut are badly damaged, the shaft must be renewed.

Cylinder Heads.—Broken or cracked fins should have these trimmed smooth with a file, if not extensively damaged. Polish the inside of the heads.

Valves.—The faces and seats are considered by their construction to be durable enough not to require attention at this stage. Both stellited and nitrided surfaces are extremely hard, and cannot be machined in the customary manner. Should the seating surfaces be very discoloured, they may be lapped together with a little metal polish to restore the finish. Otherwise they should only be wiped clean. The ends of valve stems, if scored or marked can be restored by stoning up smooth and polishing. Replace broken valve springs, or those under the limits of the load.

Pistons.—Slight scores may be removed from piston skirts with a smooth file, and afterwards polishing. Defective rings, if any, must be replaced by new ones. Gudgeon pin bores must not be touched at all but the fit of the pins should be checked, as this is important. Polish all piston crowns.

General.—All parts which have been stoned, polished, or similarly treated, must be washed perfectly clean and free from metal particles, and dried by an air blast. Particular care must be taken to remove all traces of abrasive and foreign matter.

Numbering and Marking of Parts.—The numbering and marking of the parts which have been dismantled is important, and the following must be carefully noted when dismantling and assembling.

Pistons.—Stamped with engine number on piston crowns near to gudgeon pin bores. Cylinder numbers stamped on the gudgeon pin bosses inside the pistons in the order S1 to S12 for those in R.H. banks and P1 and P12 for those in L.H. banks. These numbers should be at the rear when the pistons are assembled in position in the engine.

The gudgeon pins and end washers are not marked, but must be retained with their individual pistons.

Rocker Spindles (with Rockers assembled on them).—Marked on their plugged ends for top R.H. front, top R.H. rear, top L.H. front, top L.H. rear, etc., thus:—T.S.F. and T.S.R., T.P.F. and T.P.R.; also B.S.F. and B.S.R., B.P.F. and B.P.R. for the lower banks.

Rocker Caps.—There are two caps on each side of the rockers for the front cylinders, each cap carrying the same number. The correct position of each cap is determined easily by its shape.

Right-hand top casing, rear end, S1 to S6 continuing in lower R.H. bank S7 to S12. Left-hand top casing, rear end, P1 to P6 continuing in lower L.H. bank P7 to P12.

Camshaft Casings.—The location letters are stamped on the exhaust side of the rear face, thus:—

L.H. top casing marked T.P.

L.H. bottom casing marked B.P.

R.H. top casing marked T.S.

R.H. bottom casing marked B.S.

Cylinder Barrels.—Stamped S1 to S12 for R.H. top and bottom banks, and P1 to P12 for L.H. top and bottom banks, on the crankcase flanges. These and the corresponding numbers on the crankcase are close together when the cylinders are fitted in position.

The joint rings are numbered similarly, and must be fitted so that the number on each one is close to the corresponding one in the spigot of each cylinder head.

Valves.—These are stamped each with their individual cylinder numbers, thus :—

Inlets P1 to P12 and Exhaust P1 to P12 for both L.H. banks; and Inlets S1 to S12 and Exhausts S1 to S12 for both R.H. banks.

The letter is stamped on one side of the head, and the number on the opposite side. Inlet valves can be distinguished from exhaust valves by their waisted stems, the exhaust valves having parallel stems. Valve collets should be retained in pairs, and bear a distinguishing mark, but the spring retainers are not marked.

RE-ASSEMBLY.

NOTE.—The gaskets for the camshaft casing covers, if damaged, the joint washers at all oil pipe joint flanges, and all tab washers, circlips, and split pins, which have been disturbed, must be replaced by new ones.

Induction pipe joints in " Nordoil " material should not require renewing unless damaged. Copper-asbestos exhaust port and sparking plug washers must also be renewed. The working surfaces of all moving parts must be oiled liberally, and the numbering strictly observed when assembling.

Headers.—Assemble the valves, springs, retainers, and collets in their correct guides, using the valve spring compressing tool No. 41772 and special collet tweezers No. 42101 for fitting the retainer and cotters.

Fit the piston rings to the pistons and the pistons to their respective connecting rods. Oil and fit the gudgeon pins and retaining washers, and secure these with new spring circlips, which are to be fitted as follows :—Thread a new circlip on to the guide No. 43651, insert the shank of the guide into the gudgeon pin and fit the ram No. 43650 on to the barrel of the guide. A smart blow with the hand upon the knurled end of the ram will force the circlip into its groove in the gudgeon pin without unduly stressing it. Ensure that the crankcase faces are clean and perfectly smooth. Taking each bank in turn, fit the cylinders and joint rings in position. Lower the correct header unit into position on the cylinders, and fit the nuts loosely to the long studs.

Ensure that the header is seating evenly on the cylinders, and screw the nuts down. Then tighten the nuts hard, beginning at the *rear* end and tightening in order, advancing towards the forward end. The nuts must always be tightened in the above order as the rear cylinder is spigoted in position and locates the header. Repeat the procedure for each bank of cylinders, rotating the engine on the stand to bring the lower banks uppermost for convenience.

Timing Valves (Fig. 26).—In timing the engine it should be noted that the timing figures quoted in page 218 and shown in Fig. 26 do not represent the actual opening and closing positions of the valves under running conditions. The figures given in page 218 and for use in conjunction with the dummy rockers referred to in item 1. But the actual running figures are brought about chiefly by the action of the hydraulic tappets which eliminate valve clearances. As the running settings cannot be obtained or checked owing to a number of arbitrary factors which exist only when the engine is running, it will be understood that they are given as a matter of interest.

Inlet opens	40° Early.
Inlet closes	70° Late.
Exhaust open	79° Early
Exhaust closes	31° Late.

Timing is now undertaken as follows :—

The valves are timed on cylinder Nos. R.H.1, L.H.6, R.H.9, and L.H.10, in the firing order.

Fit the piston position indicator No. 41786 to No. R.H.1 cylinder, and turn the airscrew shaft in the normal rotational direction by means of the tool No. 41925 to bring the piston up to T.D.C. as indicated approximately.

Fit the two dummy rockers No. 74793 to the valves of No. R.H.1 cylinder, and set the clearance between the cams and adjustable pads at 0·10 in. by the gauge No. 41958.

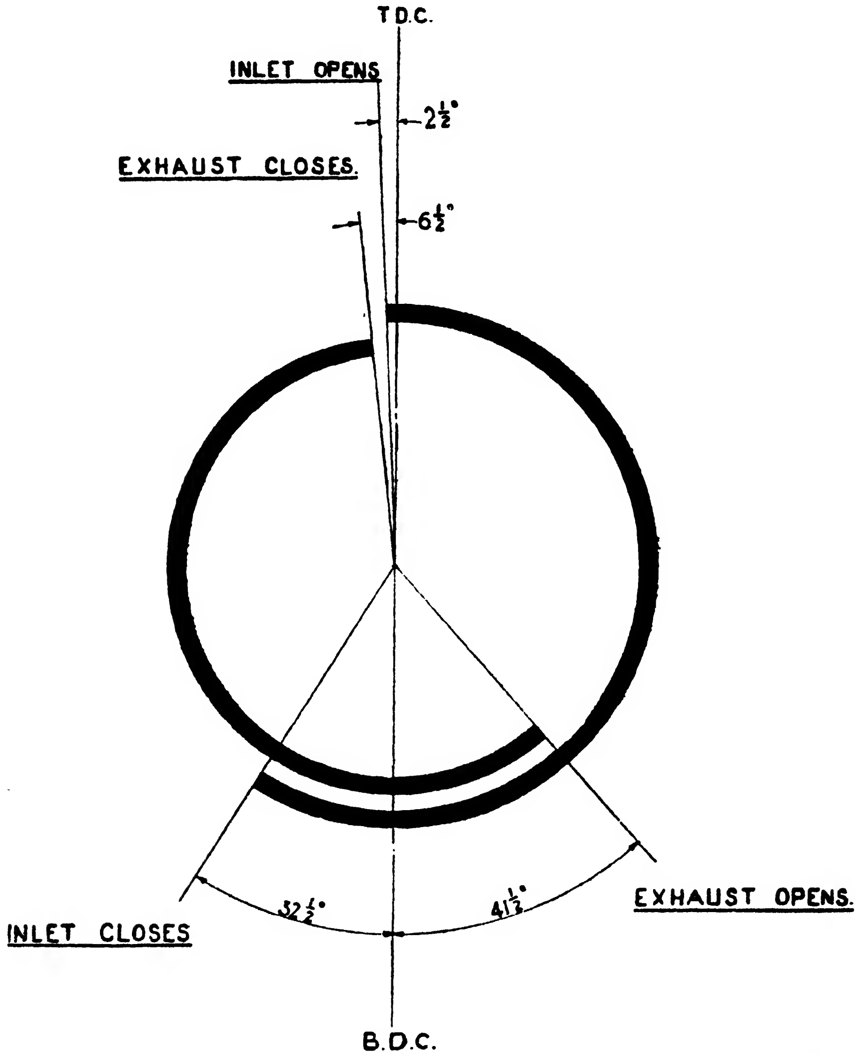


Fig. 26.—Timing Diagram. (Figures used for Setting Timing with Dummy Rockers).

To find true T.D.C. :—

Set the timing fixture No. 41992 on the camshaft casing of the L.H. top bank of cylinders, and engage the bevel gear with the camshaft bevel gear. This is for convenience when setting the R.H. camshaft vernier.

Draw the camshaft drive shaft bevel of the R.H. top bank into engagement with the camshaft bevel gear, and secure the housing temporarily with the two stud nuts.

Turn the lower timing dial until T.D.C. S.1 (zero) is indicated at the pointer, and tighten the three central thumb nuts.

Turn the engine until the dial indicates say 20° to the left of zero, set the position of the mark on the piston position indicator to the pointer. Turn the engine to the *right* of approximate zero until the piston position indicator stands at the mark again.

Note the difference between the dial reading and the 20° mark on the right of zero. Halve this difference, (*i.e.* the total error), and reset the dial by this amount towards the 20° mark. To check, turn the engine until 20° to the left of zero is registered, and reset the piston position indicator as above.

Turn the engine till the dial registers 20° to the right of zero, and if the piston position indicator is standing at the mark on the adjustable segment, then true T.D.C. is established at the zero dial reading.

Now set the upper dial with the " O " mark at T.D.C. S.1 on the lower dial, and secure with the single thumb nut. Now turn the airscrew shaft in the reverse of normal, rotational direction well past the " I.O." (Inlet Opens) mark, and then bring it up to the " I.O." mark in the normal direction of rotation, so that the backlash is on the correct side. Remove the nuts holding the camshaft bevel to the camshaft. Slacken the camshaft drive shaft, and disengage the gears.

Do not alter the Piston position—Now turn the camshaft until the Inlet Valve of No. R.H.1 cylinder just commences to open the valve. This is evident when it is no longer possible to slide the dummy rocker to and fro endways by hand.

The drive to the camshaft should now be connected up, but as it is more than likely that it will not be possible to do this without some adjustment, the following data should be noted.

The Bevel Gear has 18 holes in the flange,	1 hole=20°
The Camshaft Flange has 15 holes - -	1 hole=24°
The Camshaft Bevel Gear has 32 teeth -	1 tooth=$11\frac{1}{4}$°

Therefore two teeth back and one camshaft flange hole forward will give 3° nett advance thus :—

1 Camshaft Flange Hole	=	24°
2 Teeth = $2 \times 11\frac{1}{4}$	=	$22\frac{1}{2}$° on camshaft.
Nett Advance = 24° — $22\frac{1}{2}$°	=	$1\frac{1}{2}$°
	=	3° on crankshaft.

As the tolerance on valve timing is ±5°, this adjustment should be adequate to enable accurate timing to be obtained. Having found the position where the gears will mesh, and three holes in the bevel gear and camshaft flanges are in line, so that they can be bolted up temporarily, check the position of the opening and closing of both valves to the markings on the upper dial.

All being satisfactory, change the timing fixture to the R.H. top bank and check for correct T.D.C. position. Turn the engine in the normal direction until the lower dial of the timing fixture reads " T.D.C.P.6."

Repeat the instructions for finding correct valve timing on the L.H. bank. Repeat the procedure for the lower banks, still keeping the timing fixture fitted to the R.H. top bank. Check the timing of both valves as before in each case. All being satisfactory, lock the bolts of the camshaft driving flanges, and remove the timing dial, p.p. indicator, dummy rockers, etc.

Timing (Ignition).—Check this if the magnetos or front cover have been removed. The ignition is timed on No. L.H.1 cylinder. Remove the blanking plate to the L.H. crankshaft from the front cover, and fit the magneto timing dial No. 45653 to the outermost pair of studs.

Turn the airscrew shaft so that the piston of No. L.H.1 cylinder is on the compression stroke, *i.e.* with both valves closed. The slot in the front end of the L.H. crankshaft lies to the outside of the engine. Insert the pointer body into the crankshaft, so that the peg in the body fits into the slot. Tighten the expanding bolt.

Fit the clamps No. 44872 to the Automatic Timing Device (A.T.D.) of the L.H. magneto to give " Full Advance." Turn the engine so that the pointer indicates " Port mag. breaks." Remove the lower screw in each of the insulated blocks in the make-and-break upon which the adjustable contacts are mounted.

Turn the magneto in the normal direction of rotation until the points operated by the inner cam are just about to break.

Fit the magneto to the engine with the make-and-break points uppermost, using the vernier adjustment, if necessary, to correct any discrepancy, and secure the magneto. Connect an electric handlamp and battery between the insulated block of the inner make-and-break and the engine.

The lamp will light when the contact points are closed.

Turn the engine back and bring the pointers up to the foregoing mark again. The light should be extinguished just as the pointer reaches the mark. Replace the screw in the make-and-break blocks and remove the clamps.

NOTE.—The engine must *not* be turned beyond the range of the dial to avoid damaging the front cover.

Check the setting of the outer cam in the same manner to the figures given on page 219.

Time the R.H. magneto in the same manner using the inner cam and the setting " Starb. mag. breaks " on the dial.

Having removed both distributors, fit the timing segment No. 41984 to each distributor base in turn, and with the L.H. magneto set as for timing, check the distributor brush position. The timing segment should be set with the small pillar at the same position as the segment in the distributor for No. L.H.1 cylinder. When the inner make-and-break contacts of the L.H. magneto are parting at the foregoing setting, the leading edge of the rotor brush should be overlapping the segment pillar to the extent of 3/64 in. from the trailing side of the pillar.

To adjust this, slacken the nuts holding the distributor base to the front cover, and turn the base as required, securing after adjustment. The base of each distributor has slotted holes to permit this being done.

Remove the magneto timing dial, the segment and pointer, and fit the distributor blocks.

Final Items.—Fit the valve rockers to the camshaft casings, and secure the caps in position. Fit dummy sparking plugs. Check over all nuts and tab washers and thoroughly oil the rocker gear with engine oil. Secure the camshaft driving shaft housing, cover tubes, and glands in position.

Fit new gaskets to the camshaft casing faces and follow with the cover plates.

Fit the gauze strainers to the camshaft casings.

Fit the induction pipes and secure the gland nuts with locking wire.

Replace the air deflector plates and oil pipes, ignition wires, clips, brackets, and bonding. Fit the sparking plugs, and secure the ignition wires.

Instal the engine in the aircraft. (Pages 249 to 252). Fit the air chutes, air intake and exhaust manifold, after making a general examination of the engine to check tightness of nuts, unions, etc.

Final Inspection as for initial Ground Test (page 255 excepting item 5).

Running up after Overhaul.—After top overhaul the engines must be tested either on a Heenan-Froude dynamometer, or, if this is not available, by means of a wooden test airscrew.

This is calibrated to permit the engine to attain a speed of 3500 R.P.M. at maximum cruising output. The test is to be conducted according to the instructions given in Air Publication 1208.

MAINTENANCE SCHEDULE.

INSPECTION BETWEEN FLIGHTS.

1. See that the ignition switches are "off."
2. Make a general examination of fuel and oil systems for leaks.
3. Replenish fuel and oil tanks if necessary, ensure that the filler caps are secure and tank vents are clear.
4. Check spinner cowling for security.

INSPECTION DAILY.

1. **Ignition.**—Inspect the switches for correct mechanical functioning and see that they are "off."
2. See that all H.T. Leads and sparking plug terminals are secure and undamaged.
3. **Fuel System.**—Inspect unions, tanks and pipe lines for leaks (all tanks on).
4. **Oil System.**—Inspect oil pipes, tanks and unions for leaks.
5. **Airscrew.**—See that airscrew hub is tight on airscrew shaft.

NOTE.—After initial attachment, the airscrew should be examined for tightness at the end of each of the first two or three flights.

6. **Controls.**—Test throttle and mixture controls from cockpit and linkage from boost control for freedom of movement.
7. **Starting.**—See that starter clutch control is not binding.
8. **General.**—Inspect engine for oil leaks and remove all oil and dirt from the installation.
9. Inspect cowling for security.
10. Remove all loose tools and rag from the engine and aircraft.

INSPECTION EVERY 10 HOURS.

1. **Ignition.**—Check the gap between the magneto make-and-break. Contacts in all open positions of the rocker and adjust so that the average gap is as near as possible to the specified figure.

NOTE.—If there is a difference of more than 0·003 in. the cam must be renewed.

2. Ensure that the contacts are clean and securely locked.
3. Inspect the rocker springs for discolouration.
4. Clean the make-and-break cover and inspect for damage.
5. Remove and clean distributors, ensure that the segments are not pitted and inspect bushes for damage and distributor blocks for cracks and distortion.
6. Check action of all cocks and controls in fuel system.
7. Remove and clean the pipe line filter.

NOTE.—When dismantled see that the gauze is not damaged and, when assembled, ensure that the filter is locked securely. Rags must not be used for cleaning.

8. See that the carburettor does not flood under normal working pressure.

NOTE.—With the inverted type of carburettor, any tendency to flooding will be manifested by a flow of raw fuel from the blower venturi drain pipe.

9. **Oil System.**—Remove and clean the gauze scavenge oil strainers in the oil pump unit.

NOTE.—These strainers are removed by first unscrewing the smaller and then the larger hexagonal plug in the cover plate on the bottom of the filter body at the R.H. side, and then detaching the plate itself. The removal of the smaller plug ensures that the pump casing drain valve is closed and prevents undue loss of oil.

No rag is to be used for cleaning the strainers, and all joint faces must be cleaned before assembly. Ensure that the rubber sealing ring at the *top* of the strainer body is intact.

The condition of these strainers is a guide to the condition of the engine.

10. **Exhaust System.**—Examine exhaust manifolds for security.

11. **Controls.**—Examine the linkwork of the throttle and mixture controls and see that it is secure.

Lubricate the moving joints in the complete engine control system.

12. **General.**—Check oil level in air compressor crankcase.

INSPECTION EVERY 20 HOURS.

1. **Ignition.**—Remove sparking plugs, dismantle and clean. Inspect parts for damage, re-assemble, set points at 0·012 in., and pressure test. Reject any plug which fails to spark at 100-lbs. per sq. in. Use only a trace of graphite grease on the threads when re-fitting.

2. Inspect the H.T. Leads for security and signs of damage.

3. See that the L.T. ignition wiring is free from oil, that it is secure against fire in any part of the aeroplane and not in contact with any parts likely to become hot.

4. See that all bonding is complete and secure.

5. **Fuel System.**—Uncouple the carburettor union and check that the fuel flow is not restricted.

6. Inspect Petroflex pipes for kinking and damage.

7. Remove carburettor jets, turn on fuel, and flush carburettor. Clean jets and replace, remembering to fit the fibre washers under the jet heads.

8. **Oil System.**—Warm the engine up and change the oil.

9. See that the pipes are not chafing on any parts of the aeroplane.

10. Examine the oil tank for security.

11. **Controls.**—Inspect the controls for wear and excessive play in the linkwork, check the settings of the throttle and mixture control levers.

NOTE.—When checking the settings, commence at the carburettor end of the linkwork and work back to the cockpit.

12. **Starting.**—Clean filter in doping system.

13. **Airscrew.**—Test all airscrew hub nuts for tightness.

14. **General.**—Inspect engine foot fittings and examine engine mounting for tightness and security.

15. Check all external nuts, unions and locking devices, and re-adjust if necessary.

INSPECTION EVERY 40 HOURS.

1. **Ignition System.**—Lubricate the main magnetos with one drop of light mineral oil on each make-and-break fulcrum wick, and cam lubricating pad.

2. **Fuel System.**—See that all fuel pipes are adequately supported to withstand vibration, and have packing between the clips and pipes. Ensure that the pipes are not chafing against any part of the aeroplane structure.

3. **Oil System.**—Change the Tecalemit filter element.

NOTE.—This is withdrawn from the R.H. end of the housing behind the oil sump. Re-assemble and refill, taking care to drive all air out of the pipes.

4. Clean the pump inlet strainer in the inlet flange for the pressure pump.

5. **Cylinders.**—Examine the air chutes and deflector plates for cracks and other damage.

6. Inspect exhaust manifolds for cracks, signs of burning out and general condition.

7. Remove camshaft casing covers and inspect valve gear and springs for damage. Renew any damaged gaskets for the covers.

8. Check compressions during sparking plug overhaul.

9. **General.**—Examine the generator commutator and brushes and clean if necessary.

10. Inspect the engine and installation generally for condition, and tightness of nuts and unions.

INSPECTION EVERY 120 HOURS.

1. **Ignition.**—Check the L.T. Leads for continuity and serviceability.

2. Check the gap between the distributor brushes and the segments, and see that the vent holes are clear.

3. Remove all screens from the ends of the H.T. cables. When pressure testing sparking plugs, the screens are to be fitted and tested for electrical leakage at the same time. Ensure that the spring plungers for the cable ends are clean and operate freely, and that the screen bodies and plunger insulating sleeves are undamaged.

4. **Fuel System.**—Drain, dismantle, and clean out the entire fuel system and tanks.

5. Test the rate of fuel flow with the feed pipe disconnected at the carburettor.

6. **Oil System.**—Drain, dismantle, and clean out the entire oil system, cooler and tank. Reassemble and refill, taking the necessary precautions regarding priming and oil leaks.

7. Calibrate the distant reading thermometer.

8. Remove and clean the small gauze strainers for the camshaft casing scavenge pumps.

NOTE.—These strainers are removed by undoing the small lozenge shaped plates at the ends of the lower camshaft casing covers.

SECTION III. VEE.

ROLLS-ROYCE—"KESTREL."

By the Technical Publications Dept.,
ROLLS-ROYCE, LTD.

INTRODUCTION.

The name "Rolls Royce" has been renowned in the automobile world since the foundation of the Company in 1908 and has come to be synonymous with the high standard of excellence for which the products of the Company are justly famous.

In the early part of the Great War the resources of the Company were turned to the manufacture of aero-engines for the British Government. This period of great activity resulted in the production of the Rolls-Royce "Eagle" engine, two engines of this type being used by Alcock and Brown, in 1919, for the first direct crossing of the North Atlantic, and for several other long distance flights.

In bulk and weight the Rolls-Royce aero-engine of to-day is very different from the engine it was: in efficiency, reduced frontal area, reduced fuel consumption and increased performance the Kestrel is as unlike its predecessor as possible. Kestrel engines are now doing 400 hours as a regular period without overhaul, in the Royal Air Force, compared with 60 hours for the Eagle I. engines of 1915.

The Kestrel is liquid-cooled and, like the majority of its predecessors, is a 12-cylinder Vee engine, working on the usual 4-stroke cycle, being a a direct development of the F.X. engine produced in 1927.

In order to meet the varying demands of naval and military authorities all over the world, the present Kestrel series is produced in unsupercharged, moderately supercharged, and two fully supercharged types. Each of these types is available with alternative airscrew reduction gear ratios of 0·632:1, 0·553:1, or 0·477:1.

The fully supercharged or S. types are designed for operation in fighter and interceptor aircraft demanding maximum performance at high altitudes.

The moderately supercharged or MS. type is intended primarily for flying boats and other aircraft having an operational height of about 5000 ft. but which demand long range and hence low fuel consumption.

The unsupercharged, or B. type, is used in bombing, reconnaissance and army co-operation aircraft where low fuel consumption and long range are essential.

All the engines, with the exception of unsupercharged type, are cleared for operation with two position controllable pitch airscrews, and all engines have been type tested for composite cooling which implies that the system may be operated right up to its boiling point, under a slight degree of pressure, which permits the use of a smaller radiator than would be

possible with a fully water-cooled system. Since the radiator is inadequate to dissipate all the heat generated on climb, a slight degree of boiling then occurs but in level flight the engine operates entirely water-cooled. By locating the radiator in a special cowl having an adjustable flap at its exit, the cooling can be controlled and the radiator drag at high speeds reduced. Composite cooling therefore reduces the direct drag due to the size of radiator and also the interference drag.

All the engines have completed the supplementary tests for running at economical cruising consumption, and dive bombing at speeds in excess of the maximum permissible speed, and are available with a wide range of standard accessories.

LEADING PARTICULARS.

The rated powers and weights of the engines referred to above are summarised in Table II.

Early Kestrel engines of series I.B., II.S., II.MS., III.S., and III.MS. differ slightly from the later types referred to above, which start with series IV., V., VI. and onwards. While the general description of the engines is similar, the later types only are referred to in the text. The following particulars refer to all later engines except where otherwise stated.

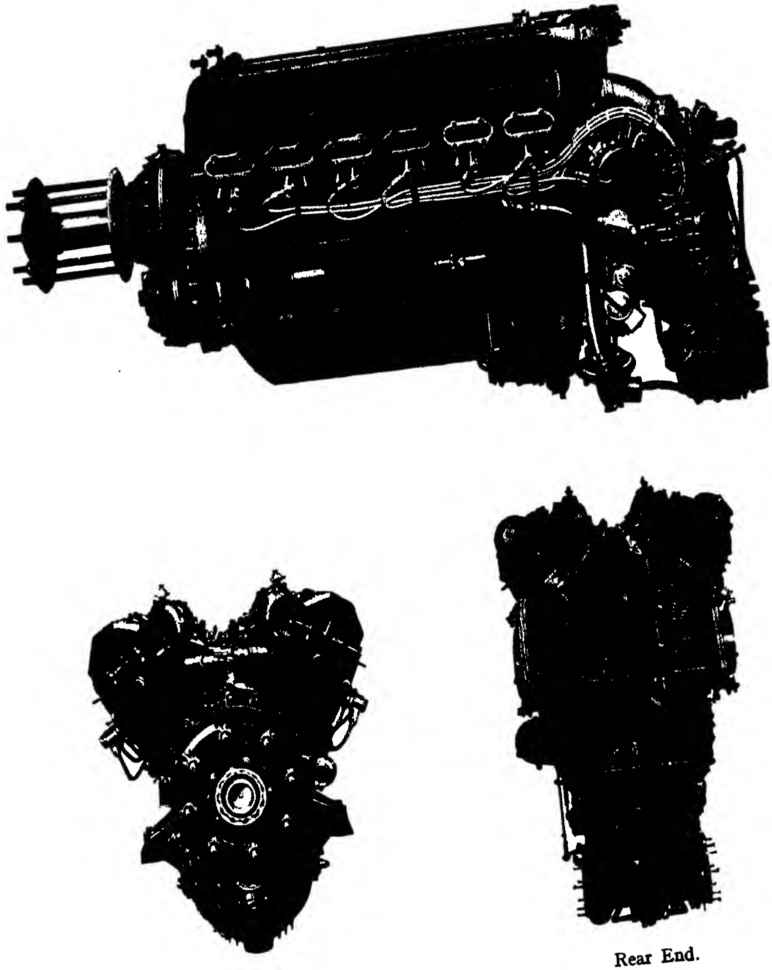
TYPE.	GEARED LIQUID-COOLED VEE ENGINE.
Number of Cylinders	12
Bore	5 ins. (127 mm.)
Stroke	5.5 ins. (139·7 mm.)
Displacement	1296 cu. ins. (21·24 litres).
Compression Ratio	6·0:1 (supercharged engines). 7·0:1 (naturally aspirated engines).
Reduction Gear	Spur Layshaft Single Reduction.
Alternative Ratios	0·632:1 0·553:1 0·477:1
Direction of Rotation—Airscrew	Right-hand Tractor.
Crankshaft,	Counterclockwise viewed from rear of engine.
Carburettor	Rolls-Royce design and manufacture. Twin choke type with mixture control. Boost control fitted to supercharged engines.
Fuel	D.T.D.230 (87 octane).
Lubrication	On the dry sump principle with one pressure and two scavenge pumps. High pressure supply to crankshaft and low pressure to valve gear, etc.
Lubricating Oils	See pages 280-283.
Sparking Plugs	Number—two per cylinder. Types—See Table I.
Ignition	By two 12-cylinder magnetos. Each magneto fires one plug in each cylinder. (For magneto types see Table I.)

Numbering of Cylinders—

Starboard Block - - - - - 1A., 2A., 3A., 4A., 5A., 6A.

Port Block - - - - - 1B., 2B., 3B., 4B., 5B., 6B.

(Numbered from Airscrew end).



Front End. Rear End.

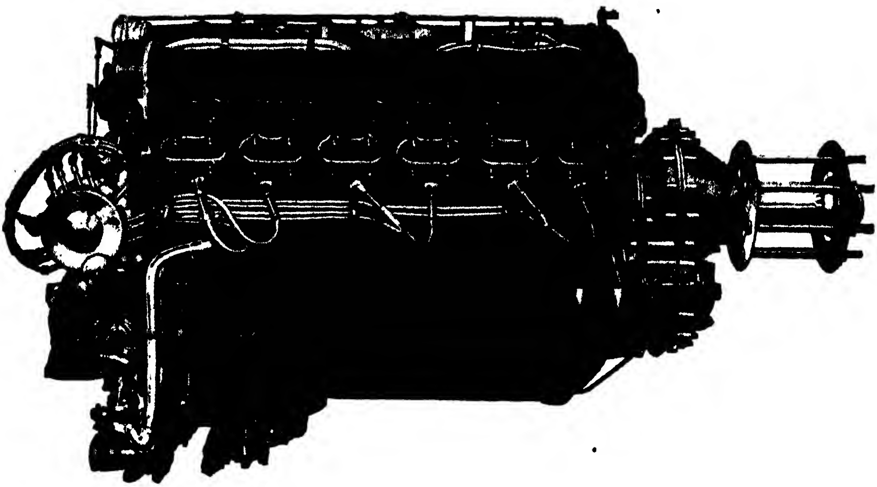
Figs. 1, 2, 3.—Rolls-Royce "Kestrel" IV. to IX.,—Supercharged.

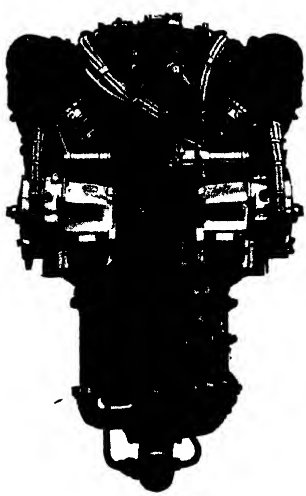
Firing Order - - - - - - - 1A., 6B., 4A., 3B., 2A., 5B., 6A.
1B., 3A., 4B., 5A., 2B.

Engine Ratings and Weights - - See Table II. (pp. 281, 282).

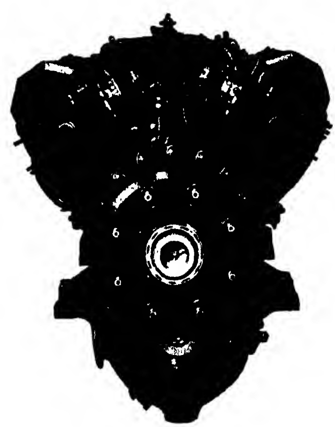
LUBRICATING OILS.

Kestrel engines are designed for use with mineral oil to the British Air Ministry specification D.T.D.109 which excludes castor or other vegetable base oils.





Rear End.



Front End.

Figs. 4, 5, 6.—Rolls-Royce " Kestrel " X.—Normally Aspirated.

Besides conforming to this specification which covers laboratory tests of the physical and chemical properties of the oil, it is preferable that an oil should also be submitted to an actual running test in the engine for which it is intended.

TABLE I.

Engine Type.	Series No.	Redn. Gear Ratio.	Compn. Ratio.	Ignition. Magneto.	Ignition. Sparking Plug.	Lubrication. Oil Pressures. High.	Lubrication. Oil Pressures. Low.	Lubrication. Oil Inlet Temps. °C. Max.	Lubrication. Oil Inlet Temps. °C. Min. for T.O.	Overall Dimensions—Inches. Length.*	Overall Dimensions—Inches. Width.	Overall Dimensions—Inches. Height.
Kestrel Fully Super-Charged	IV V VI	0·632 0·553 0·477	6·0	B.T.H. SC. 12-7D or Watford SP. 12-3	K.L.G. V7/3B† or K.L.G. V9/1B Lodge A5/B	60 Min. 30	10	90	15	62·45	24·4	37·075
Kestrel Moderately Super-Charged	VII VIII IX	0·632 0·553 0·477	6·0	Watford SP. 12-3	K.L.G. V7/3B or K.L.G. V9/B Lodge A5/B	60 Min. 30	10	90	15	62·45	24·4	37·075
Kestrel Normally Aspirated	X XI XII	0·632 0·553 0·477	7·0	B.T.H. SC. 12-7 D	K.L.G. V9/1 Lodge A2/2	40-60 Min. 30	6-8	90	15	57·15	24·4	39·025
Kestrel Fully Super-Charged	XIV XV XVI	0·632 0·553 0·477	6·0	B.T.H. SC. 12-7D or Watford SP. 12-3	K.L.G. 893/B or K.L.G. 769/B Lodge A5/B	60 Min. 40	5 Min. 3	90	15	62·45	24·4	37·075

* Lengths given to rear flange of airscrew hub.
† The suffix "B" denotes that the plug has a ball-end terminal to suit the screened ignition fittings supplied.
The list of sparking plugs authorised is liable to amendment as new types are approved.

TABLE II.

Kestrel Series No.	Type.	Reduction Gear Ratio.	RATING. International. B.H.P.	International. R.P.M.	International. Altitude feet	International. Boost lbs./sq. in.	Maximum Power. B.H.P.	Maximum Power. R.P.M.	Maximum Power. Altitude feet	Maximum Power. Boost lbs./sq. in.	Maximum Take-Off. Boost lbs./sq. in.	Maximum Take-Off. R.P.M.	Maximum Take-Off. B.H.P.	Nett dry weight lbs.	Oil Consumption pints/hr.
X, XI, XII	Naturally Aspirated	0·632, 0·553, 0·477	585	2500	S.L.	...	635	2900	S.L.	...	...	2500	585	886	6
			(Rating with fixed pitch airscrew)												
IV, V, VI	Fully Supercharged	0·632, 0·553, 0·477	600	2500	11,000	+1½	640	2900	14,000	+1½	+6	2500	745	955	6
					(Rating with fixed pitch airscrew)										
			635	2750	13,000	+1½	640	2900	14,000	+1½	+6	2750	760	980	
					(Rating with variable pitch airscrew)										
VII, VIII, IX	Moderately Supercharged	0·632, 0·553, 0·477	675	2500	3,000	+2⅝	730	2900	5,250	+2⅝	F.T.	2500	745	955	6
					(Rating with fixed pitch airscrew)										
			725	2750	4,000	+2⅝	730	2900	5,250	+2⅝	F.T.	2750	800	991	
					(Rating with variable pitch airscrew)										
XIV, XV, XVI	Fully Supercharged	0·632, 0·553, 0·477	690	2600	11,000	+3¼	745	3000	14,500	+3¼	+6	2600	730	950	6
					(Rating with fixed pitch airscrew)										
			715	2750	12,250	+3¼	745	3000	14,500	+3¼	+6	2750	745	986	
					(Rating with variable pitch airscrew)										

For this reason Rolls-Royce Ltd. have carried out tests on various well-known brands of oil, and the following oils are recommended:—

W. B. Dick & Co. Ltd., - -	"Ilo" Aero Engine Oil "M" D.T.D.109.
Intava Ltd. - - - -	Intava Red Band, D.T.D.109.
Shell-Mex & B.P. Ltd. -	Aeroshell Medium.
Silvertown Lubricants - -	Aero Oil P.4, D.T.D.109.
,, ,, - -	"Speedolene" Aero Engine Oil, D.T.D.109.
Sternol Ltd. - - - -	Sternol Aircraft Lubricating Oil, D.T.D.109.
C. C. Wakefield & Co. Ltd. -	Castrol Aero "C" D.T.D.109.

(The order is alphabetical).

Summer grade oil should be used in mild and warm climates. For operation in cold climates, when the temperature is below 0°C., winter grade oils of the above brands should be used. When temperatures fall below −15°C., special low temperature oils are necessary.

GENERAL DESCRIPTION—SUPERCHARGED ENGINES.

This description applies to supercharged engines of series IV., V., VI., and later types. Much of the description applies also to unsupercharged engines of series X., XI., XII. which are described later.

Cylinder Block.—The starboard and port cylinder blocks are designated the "A" and "B" blocks respectively. Each cylinder block (Fig. 11) is a single aluminium casting comprising both the head and the water jacket. Six wet cylinder liners are fitted into each block, the top ends fitting with intervening aluminium joint washers against shoulders in the combustion spaces, and the lower ends having base flanges which fit against the crankcase. The resulting joints are maintained by means of fourteen long studs which run from the crankcase through to the tops of the blocks. The whole reaction of these studs is taken by the cylinder liners, and special care is necessary in tightening up to ensure sound joints at the top ends of the liners. On series XIV., XV., and XVI., engines, additional studs and clamps bearing on the top flange of the liner, help to retain the top joint, and also hold the liners in place when the block is removed from the crankcase. Access to the clamps is obtained by removing six small inspection plates at each side of the cylinder block. All but the four end studs are enclosed throughout the depth of the block by aluminium guard tubes which serve both to protect the studs from the jacket water and also to form ducts conveying oil mist to, and scavenge oil from, the camshaft casing at the top of the block.

The water joint near the base of each liner is made by means of a spring-loaded rubber ring (Fig. 11) which fits an external groove in the liner and is compressed by the bore of the mouth of the block. As the water jacket does not make contact with the crankcase, any water leakage at these joints is carried to the outside of the engine.

Two inlet and two exhaust valves open into each combustion space. The inlet ports of each three adjacent cylinders unite to form four inwardly directed induction facings, while the exhaust ports are separate, one for each cylinder, and face outwards. Screwed-in valve seats are fitted, aluminium-bronze for the inlet and nickel molybdenum chrome steel for the exhaust.

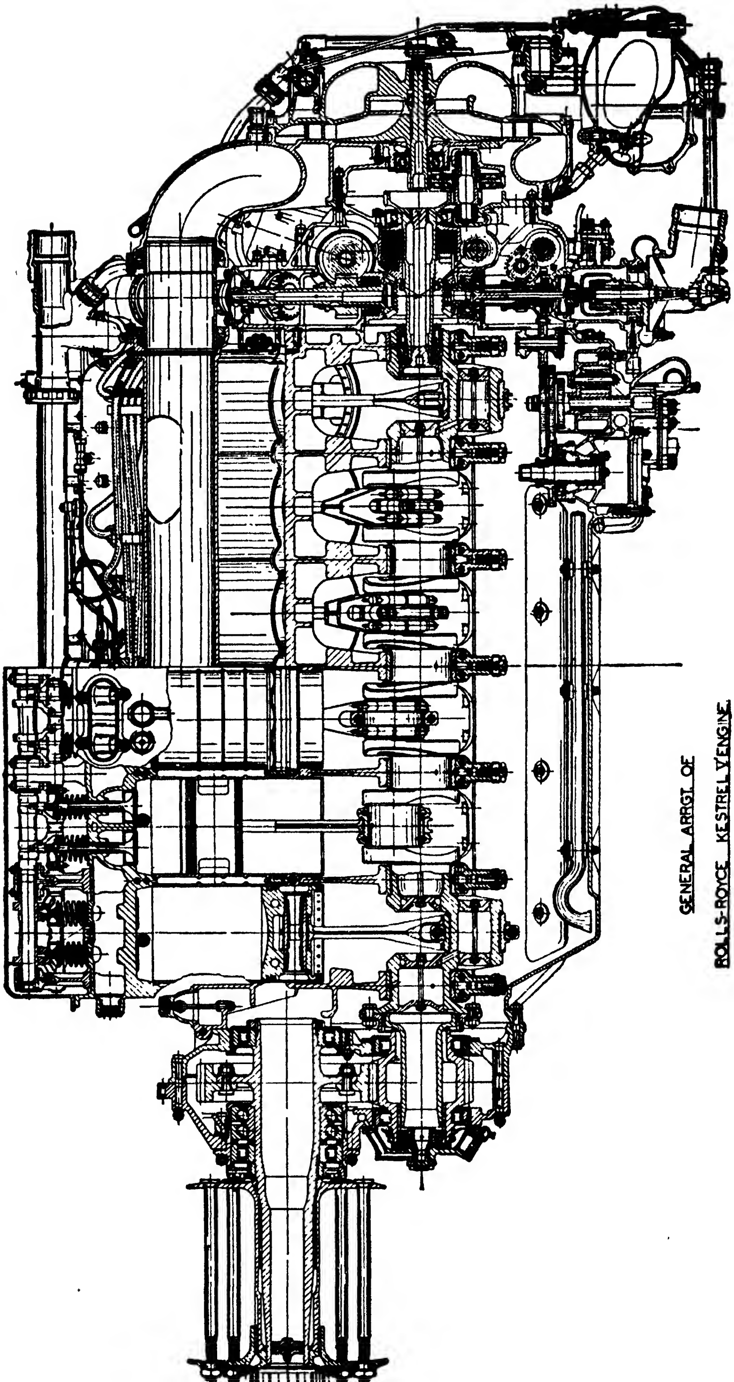


Fig. 7.—Sectional View of Supercharged Kestrel Engine.

Facings on the top of the block take the pedestals for the camshaft bearings and the rocker shafts. A single central camshaft is provided for

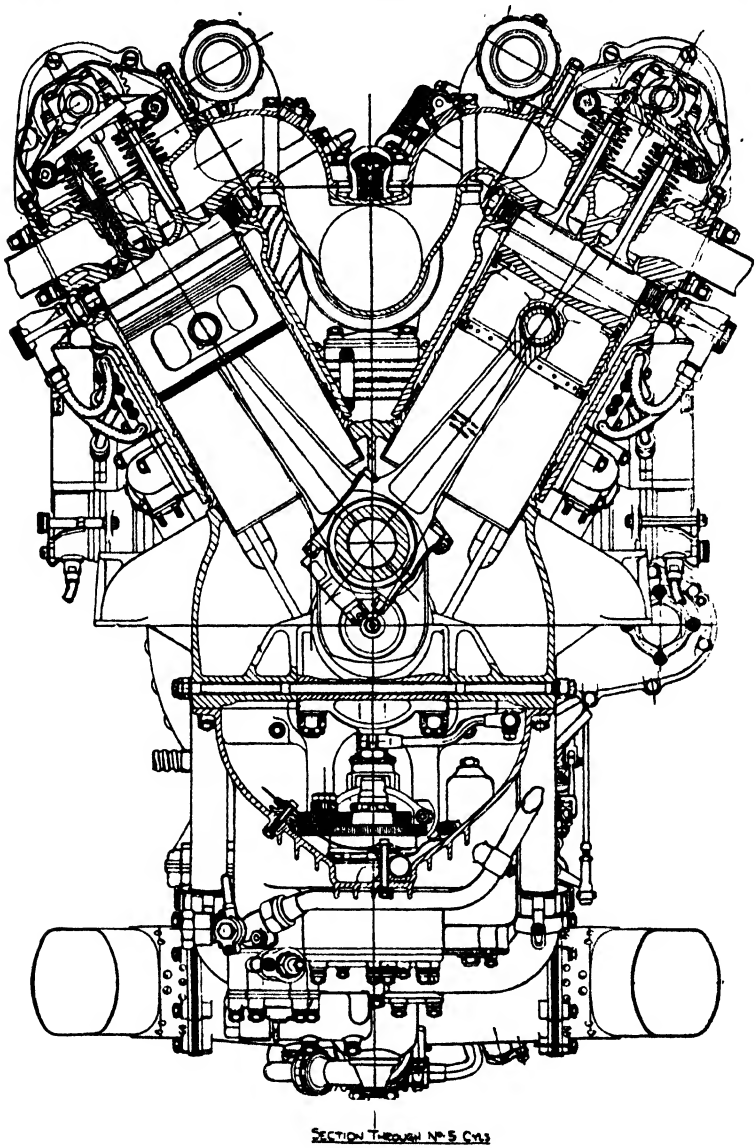


Fig. 8.—Sectional View of Supercharged Kestrel Engine.

each block and the valves are operated by rockers. The camshafts are driven (geared down 2 : 1, *i.e.*, to one-half cranskhaft speed) from inclined

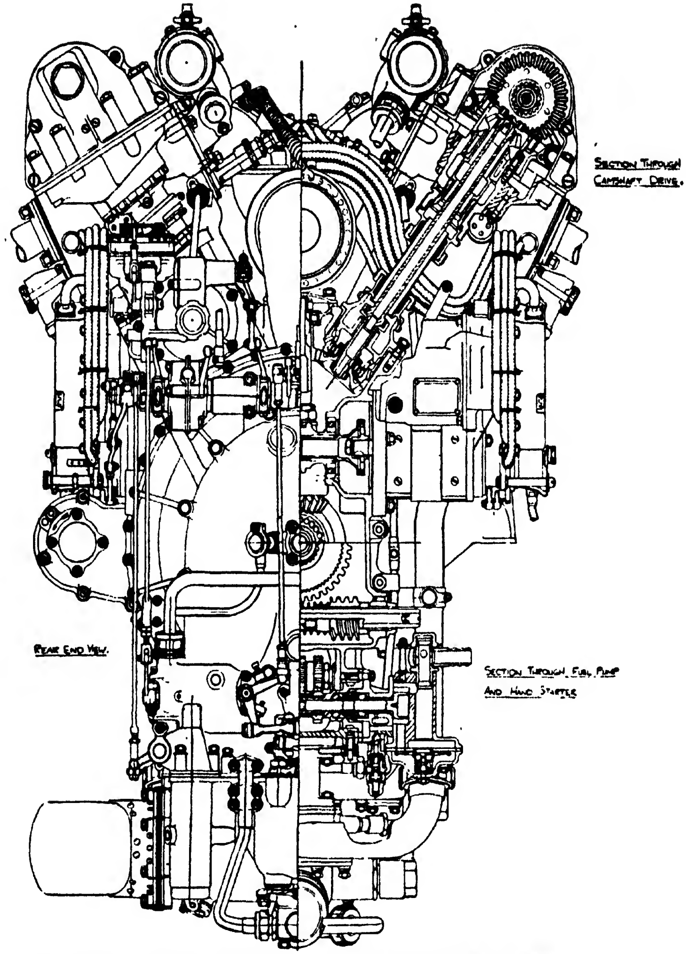


Fig. 9.—Sectional View of Supercharged Kestrel Engine.

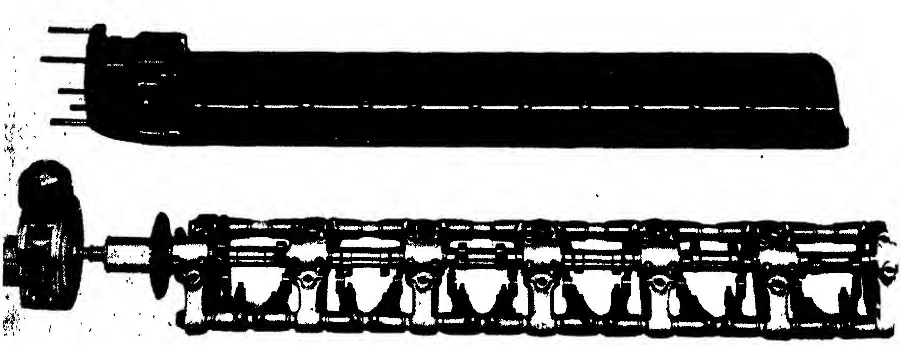


Fig. 10.—Camshaft and Rocker Mechanism, showing drive for B.T.H. Air Compressor.

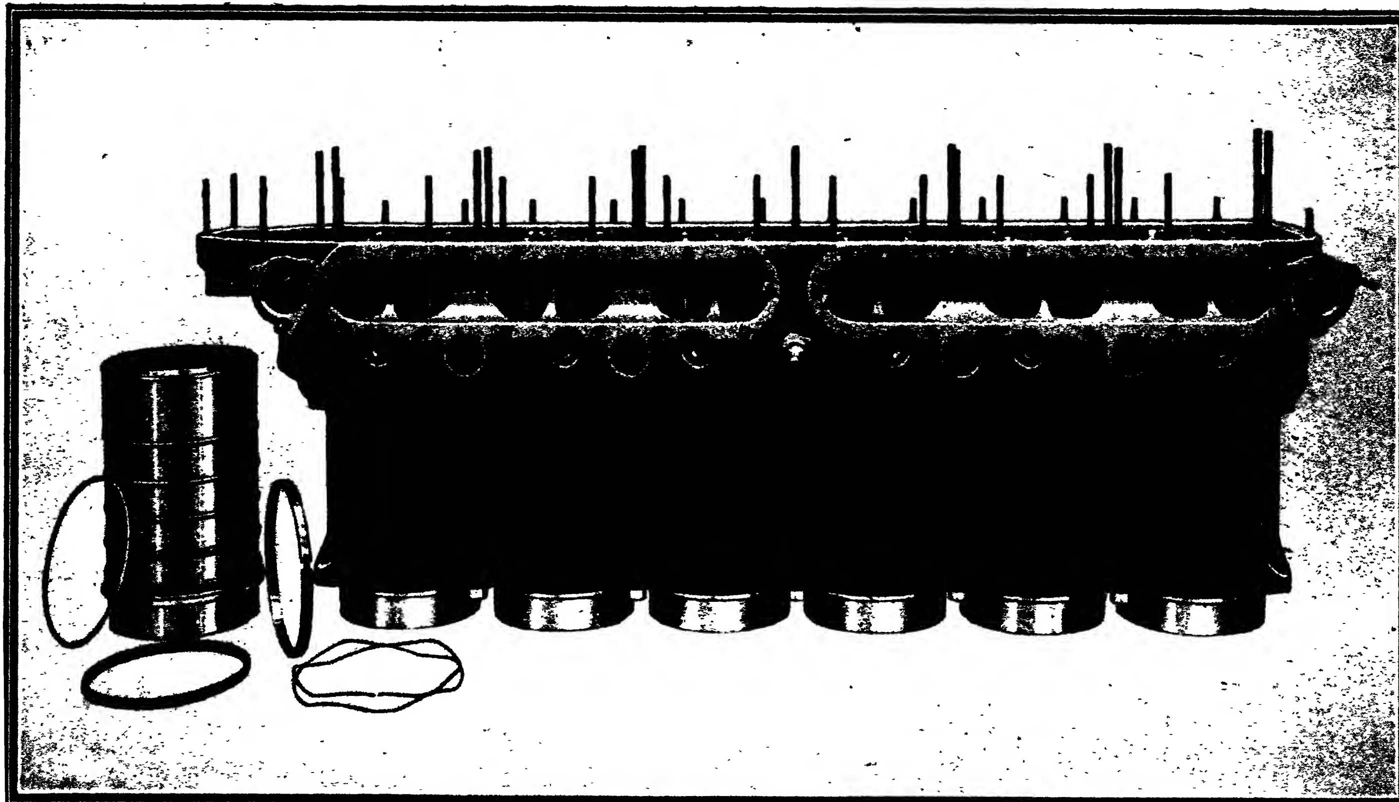


Fig. 11.—Cylinder Block and Liner with Joint and Spring Rings. (Kestrels IV. to XII.)

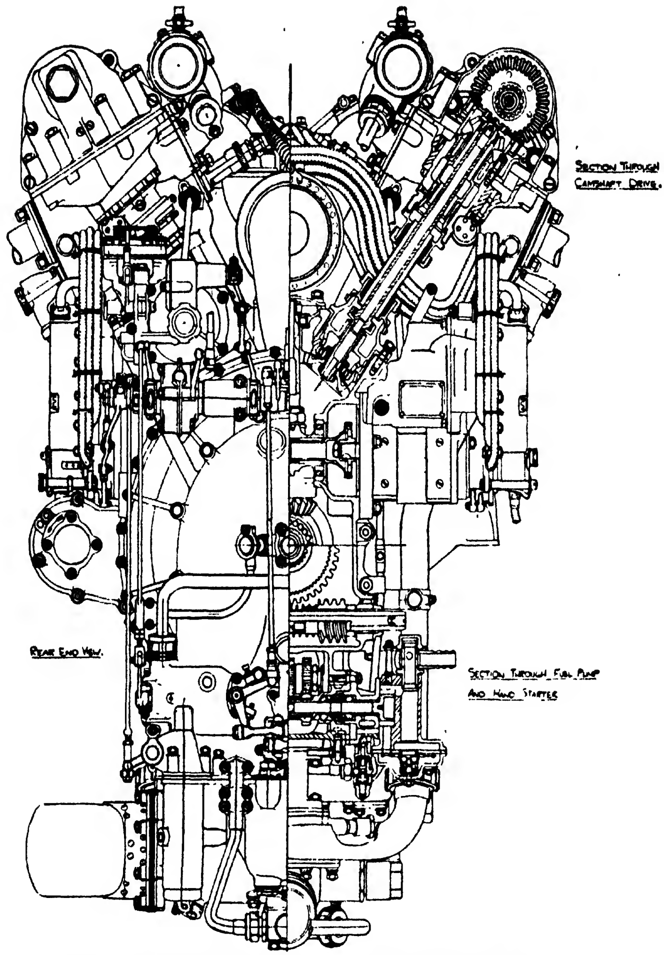


Fig. 9.—Sectional View of Supercharged Kestrel Engine.

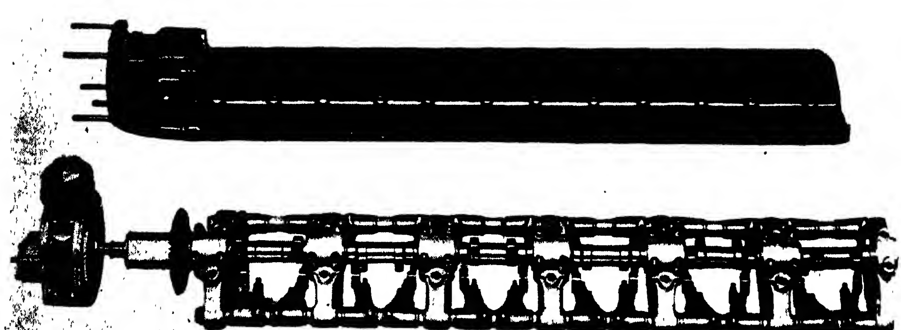


Fig. 10.—Camshaft and Rocker Me:hanism, showing drive for B.T.H. Air Compressor.

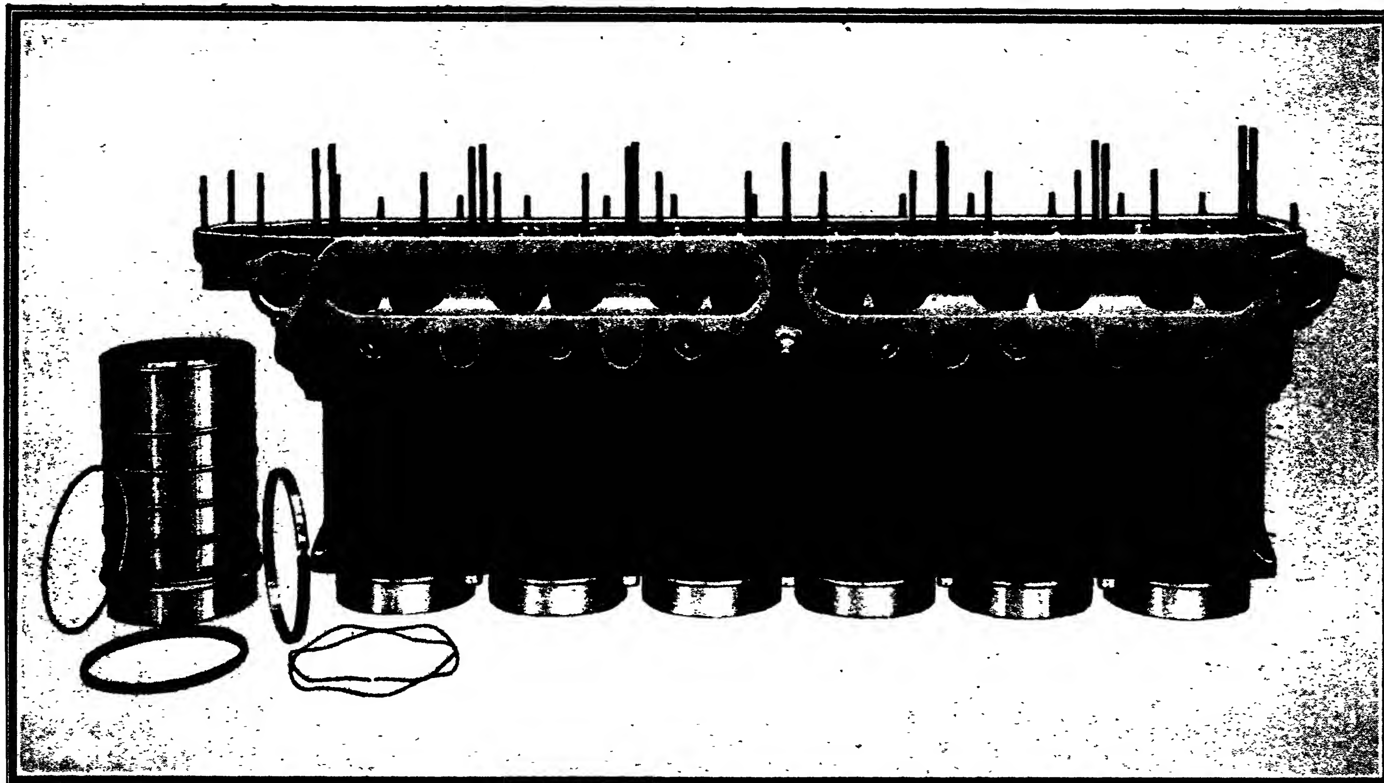


Fig. 11.—Cylinder Block and Liner with Joint and Spring Rings. (Kestrels IV. to XII.)

shafts and bevel gearing at the rear of the block (see Fig. 23). The driving shafts are enclosed by tubular sleeves, easily detachable to facilitate removal of the cylinder blocks, and are splined at the ends to form vernier couplings, whereby valve timing can be adjusted to within 1° of accuracy. The sleeves, which form return ducts for oil from the camshaft drive, are fitted with spring-loaded gland packings.

Engine Speed Indicator and Air Compressor Drives.—The rear end of the port or " B " block camshaft is fitted with a pinion which drives a shaft housed in the end of the camshaft cover by which the flexible cable to the engine speed indicator is driven at half camshaft speed. On later

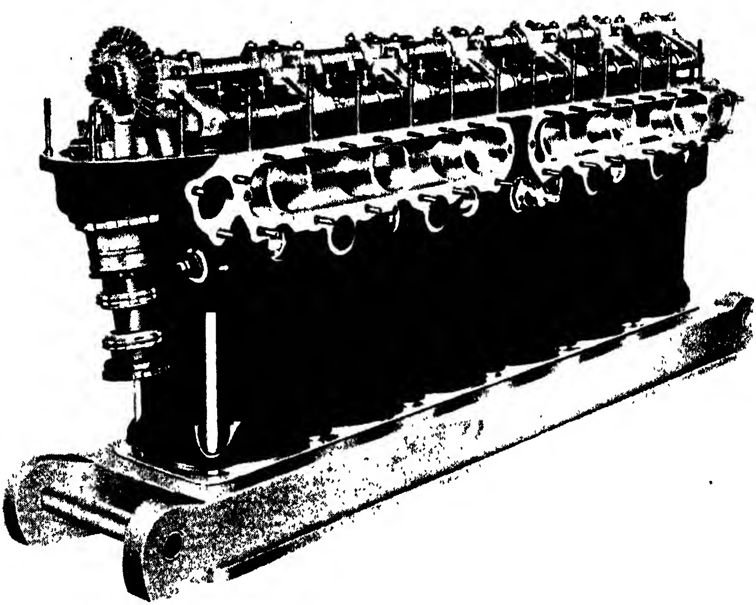


Fig. 12.—Kestrel XVI Six Stud Cylinder Block (induction side).

type engines this end cover can be replaced by one designed to carry a single cylinder air compressor in axial alignment with the camshaft and driven therefrom by a sleeve coupling ; in this case the engine speed indicator drive is taken via a 1 : 2 gear from the rear end of the compressor shaft (see Fig. 10).

Connecting Rods.—The connecting rods (Fig. 13), two of which work on each crankpin, are steel forgings of H section, machined all over. One rod is forked at the foot, and is attached by four bolts and nuts to a steel bearing block, split longitudinally along its centre line. The foot of the forked rod which mates with the block, is curved to prevent cracking at the four lugs.

The steel bearing block is lined inside with lead bronze, and bears on the crankshaft. The plain rod bears on the outside of the bearing block.

within the fork, which is metalled with lead bronze at this point. The cap of the plain rod big end, which is ground internally, is secured by two bolts and nuts.

The little end bearing of each rod consists of a floating phosphor bronze bush, with an internal groove in the connecting rod to distribute the oil.

Pistons.—The pistons (Fig. 13) are of forged aluminium alloy carrying three compression rings above the gudgeon pin axis, and one grooved scraper ring at the bottom of the skirt, in series IV. to IX. engines. A slightly different piston is fitted to series XIV., XV., and XVI. engines, having three compression and one scraper ring above the gudgeon pin, and one scraper ring at the bottom of the skirt. Segmental portions of

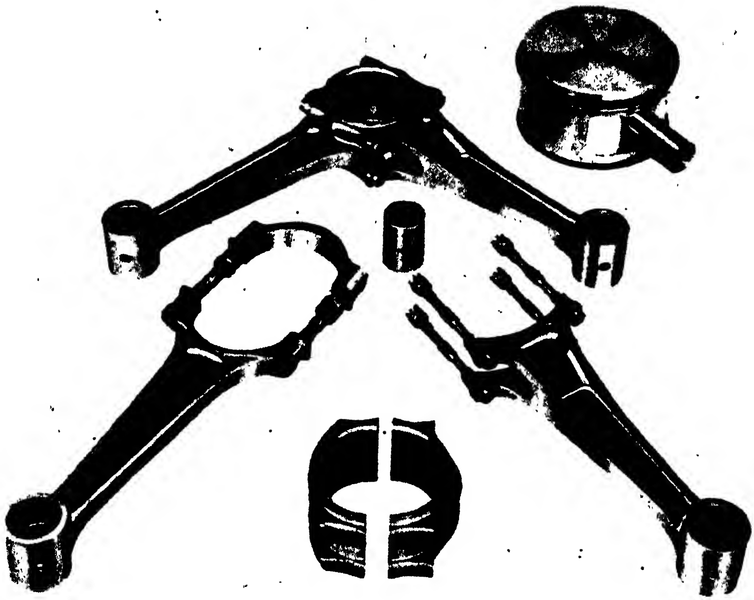


Fig. 13.—Piston, Connecting Rod and Big End Assemblies.

the piston wall are cut away in the vicinity of the gudgeon pin bosses, which are each supported by a chordal web from the piston crown. The hollow gudgeon pins are of the floating type retained in the bosses by spring circlips.

Valves.—The exhaust valve stems are hollow and partially filled with metallic sodium which is molten at the operating temperature of the valve. Due to the motion of the valve the sodium is shaken from one end of the stem to the other, assisting in the transfer of heat away from the head. The seating of the valve is coated with Stellite,—an alloy resistant to the corrosive action of the combustion products of high leaded fuels and, moreover, one which has exceptional hardness at the operating temperature of the valve.

Another feature tending to improve the life of the valve and seat is the provision of an " accommodation " angle on the exhaust valve, which is ground to an included angle of 90° 30′ while the valve seat in the cylinder head has an included angle of 90°.

Exhaust valve guides are of phosphor bronze and inlet valve guides of cast-iron. The valves are fitted with split collets and flanged sockets against which the double valve springs abut.

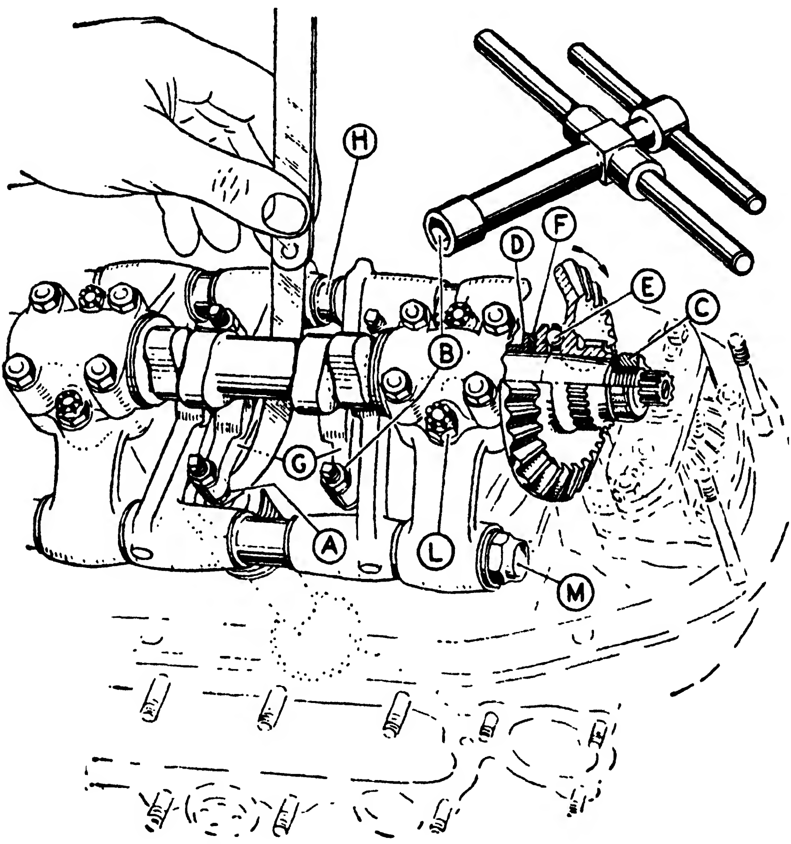


Fig. 14.—View of Rockers and Camshaft showing Tappet Adjustment.

Crankshaft.—The hollow crankshaft (Fig. 15) has seven journals and six throws. The latter are paired 1 and 6, 2 and 5, 3 and 4, in three directions, 120° apart. The rear journal is splined internally to take the coupling driving the auxiliary gears, and the forward end of the crankshaft carries a flanged member splined to take the coupling sleeve driving the reduction pinion. The crankpin and intermediate journal bores are sealed by conical plugs to retain oil supplied for lubrication purposes. Oil passes from the pressure fed main bearings to the interior of the journals through radial holes in the crankshaft, and thence to an adjacent crankpin bore

by an inclined hole through the web. Each main bearing supplies oil in this manner to the crankpin immediately behind it. The oil then passes to the big end bearings through radial holes in the crankpins.

Crankcase (Upper Half).—The crankcase (upper half) is an aluminium alloy casting (Fig. 16) with two inclined top faces bored to take the spigot ends of the cylinder liners, a forward face to take the reduction gear casing, a rearward face to take the wheelcase and a bottom face to take the crankcase lower portion. Nos. 3 and 6 cylinders fit into the crankcase with limited clearances for location purposes, the other cylinders having liberal clearances to allow for expansion. The seven bearings for the

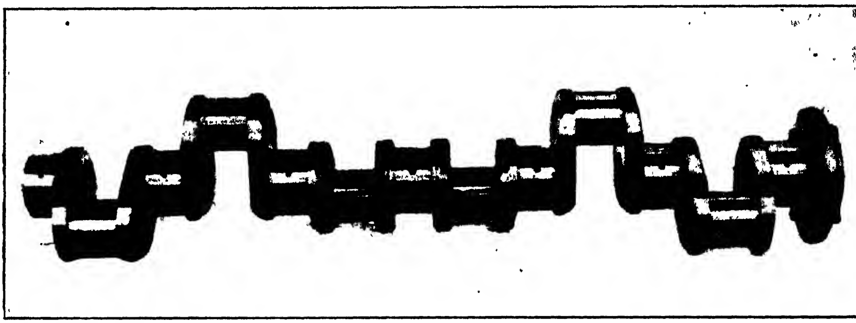


Fig. 15.—Crankshaft. (Reduction Gear Coupling Flange to right).

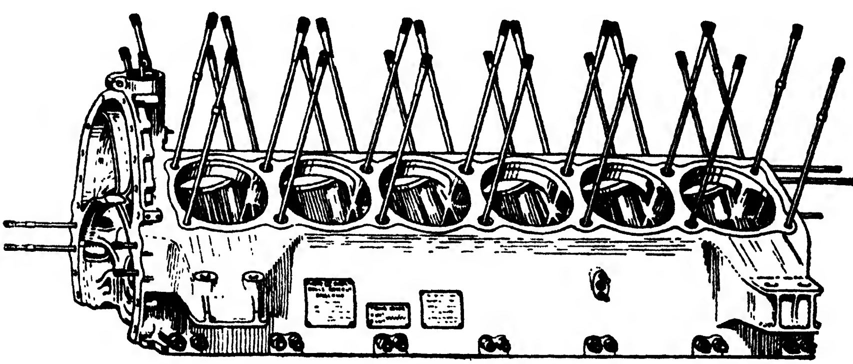


Fig. 16.—Crankcase (upper half).

crankshaft are lined with lead-bronze bearing material. The bearing caps, in addition to being held by the vertical bearing studs, are housed between closely fitting side cheeks. Transverse bolts pass through clearance holes in both crankcase and caps, and these bolts, which are tightened after the main bearing bolts have been secured, serve to increase the rigidity of the engine and to counteract the transverse components of the impulses due to the inclination of the cylinder blocks from the vertical. The crankcase walls extend at the four corners to form box-section feet by which the engine is supported.

Crankcase (Lower Half).—This portion forms a sump which is drained by the oil pumps housed on the depressed floor at the rear end of the casting (see Fig. 29). Two filters are also bedded in this portion of the crankcase, the forward filter casing having a pipe led to the forward end of the casting to scavenge the front of the engine ; the rear filter is in the scavenge circuit for the rear portion of the sump. The high-pressure oil pump and relief valves are mounted beneath the scavenge pumps on a facing on the underside of the sump. An adjacent facing is also provided for a low pressure

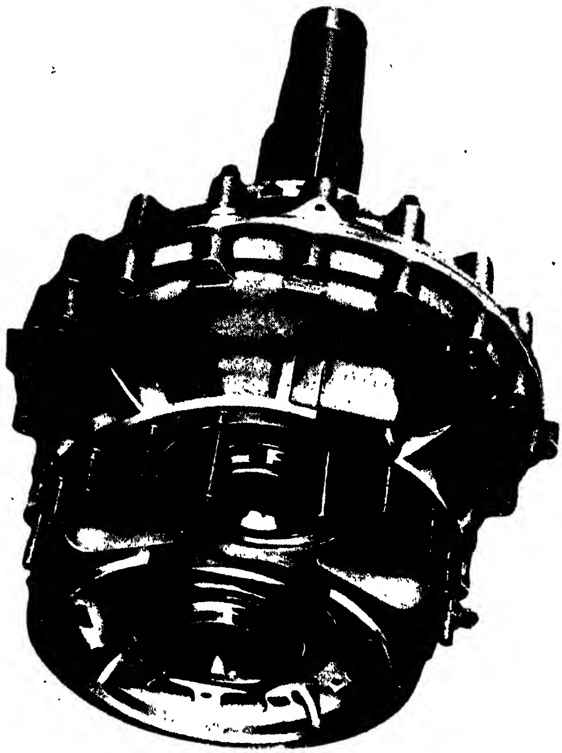


Fig. 17.—Reduction Gear Assembly.

air compressor. The crankcase lower half is ribbed to provide greater rigidity.

Reduction Gear (Figs. 17 and 18).—This is carried in a casing, bolted to the front end of the crankcase and spigoted concentric with the crankshaft. The bolts are relieved of shear stresses as two thrust stops are provided to prevent the reduction gear casing being carried round on its spigot. One of the stops is a central lug on the crankcase upper portion just in front of the breather and the other is to the right of it on the reduction gear casing ; the stops are held in contact by a transverse bolt. Both the pinion and the gear wheel above it are carried in roller bearings, the

airscrew shaft being provided additionally with a double row thrust bearing (0·632 : 1 and 0·553 : 1 ratio), or a single row thrust bearing (0·477 : 1 ratio), housed in a steel sleeve in the casing! A timing disc is mounted on the forward end of the reduction gear pinion and can be viewed when necessary after removing a screwed plug just below the pinion axis.

Airscrew Hub.—The airscrew hub, for a wooden airscrew, consists of a flanged sleeve centred between the cone and cone nut on the airscrew shaft and carries a loose flange upon serrations at its front end. An internally splined locking collar (eleven splines) is detachably mounted on five studs upon the front flange, and by engaging the splines on the cone nut. secures the nut against slackening. The collar flange has ten holes and therefore the cone nut can be locked at 3·28° intervals. Eight bolts

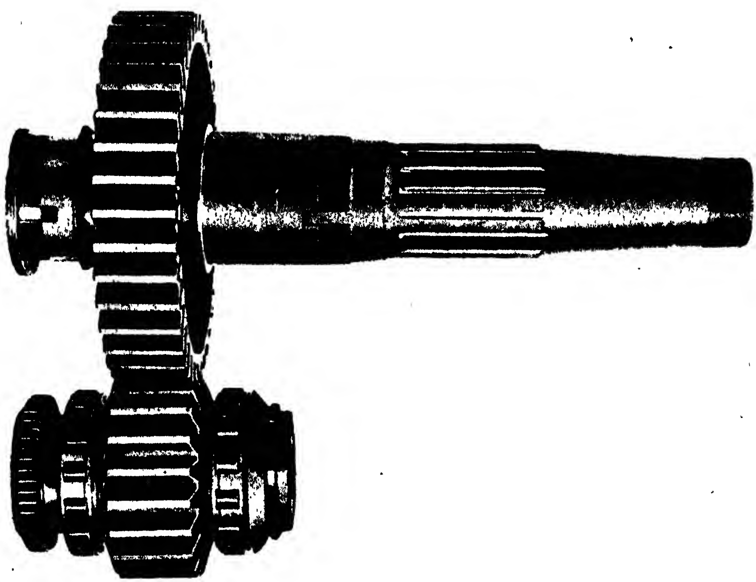


Fig. 18.—Crankshaft Pinion, Airscrew Shaft and Gear.

draw the front flange up to the airscrew boss, and also secure the Hucks starter claw, when fitted.

Variable Pitch Airscrew.—Provision can be made on later types of supercharged engine for the fitting of a De Havilland two-position variable pitch airscrew. The special parts involved include :—

(1) A high-pressure oil pump, relief valve, and pitch control cock, fitted to the rear of " B " bank camshaft cover and driven by a splined coupling piece from the camshaft bevel. (See Fig. 19).

(2) A modified reduction gear, with airscrew shaft suitable for the type of V.P. airscrew to be used.

(3) A modified oil pipe system, to couple up the high-pressure pump to the normal oil system and to the airscrew shaft connection. (See Fig. 20).

Wheelcase and Gears.—The wheelcase is attached to the rear facing of the crankcase. It carries the following units or drives :—Spring drive, hand-starting gear, lower camshaft drive, magnetos and drives, lower driving shaft, water circulating pump, gun gear cams, fuel pump, oil pump drive, compressor drive and supercharger.

Spring Drive.—This is a form of spring coupling (Fig. 21) connecting the crankshaft to the auxiliary drives whereby the torsional oscillations of the former are damped to give a steady drive to the latter. The coupling

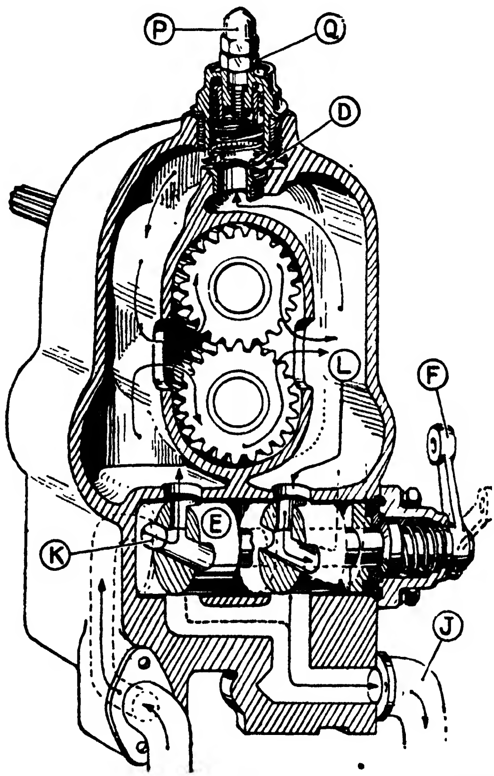


Fig. 19.—Sectional Diagram of Auxiliary Oil Pump for operating V.P. Airscrew.

consists of a slender inner shaft (L) splined, without backlash, into the rear end of the crankshaft, and into the rear end of the hollow outer shaft (B), which carries the main driving bevel wheel. The hollow outer shaft has a splined driving journal (C) keyed and bolted to its forward end. The journal portion fits a bush in the end of the crankshaft, while the splined portion fits the same splines in the crankshaft as the forward end of the inner shaft, but with considerable backlash.

The effect of this is that the hollow outer shaft does not convey drive from the crankshaft unless the amplitude of twist of the inner shaft is sufficient to take up this backlash. The hollow shaft has a spur gear at

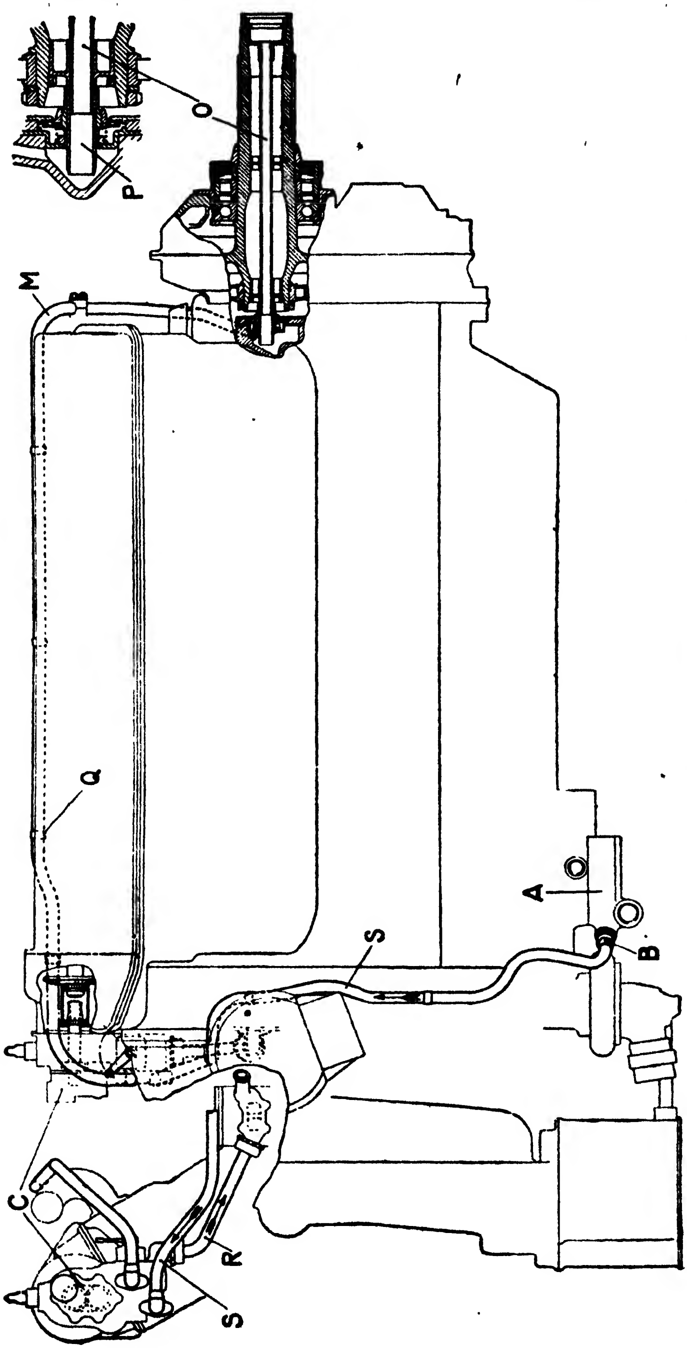


Fig. 20.—Diagram of Oil System for Operating V.P. (Two-position) Airscrew.

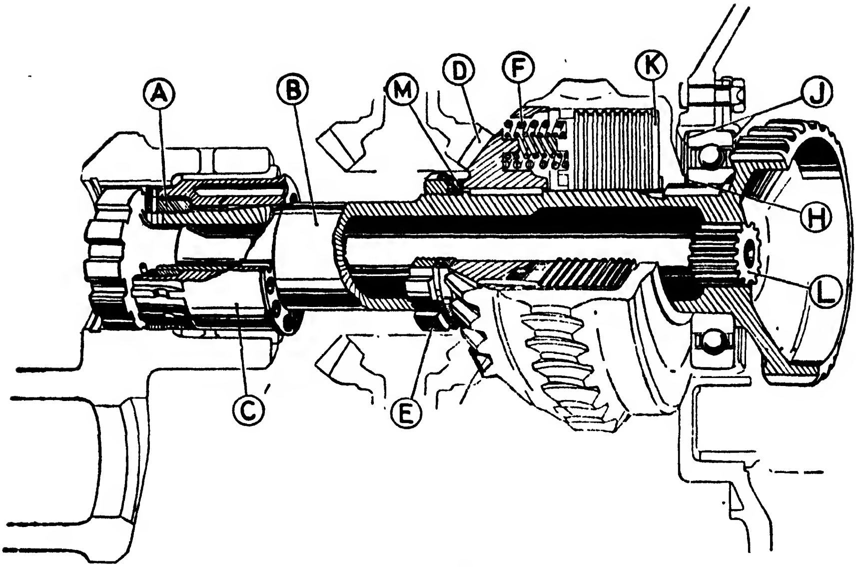


Fig. 21.—Section of Spring Drive and Hand Starter Gear.

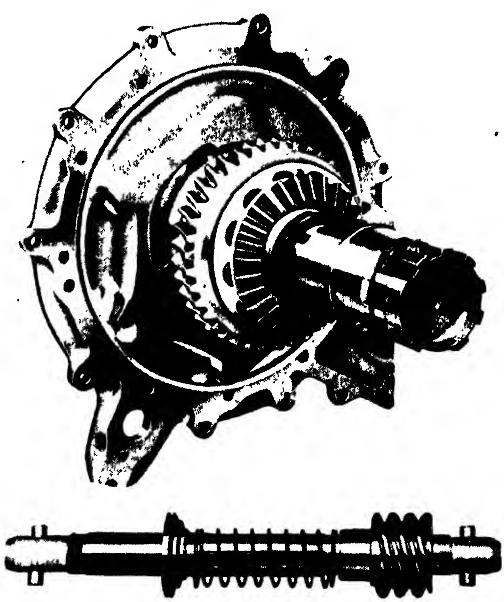


Fig. 22.—Hand Starter Mechanism.

the rear end which drives the gear train for the supercharger and generator drives.

Hand-Starting Gear.—This is of the worm-wheel type (ratio 13 : 1). The worm-wheel drives a plate clutch on the hollow outer shaft

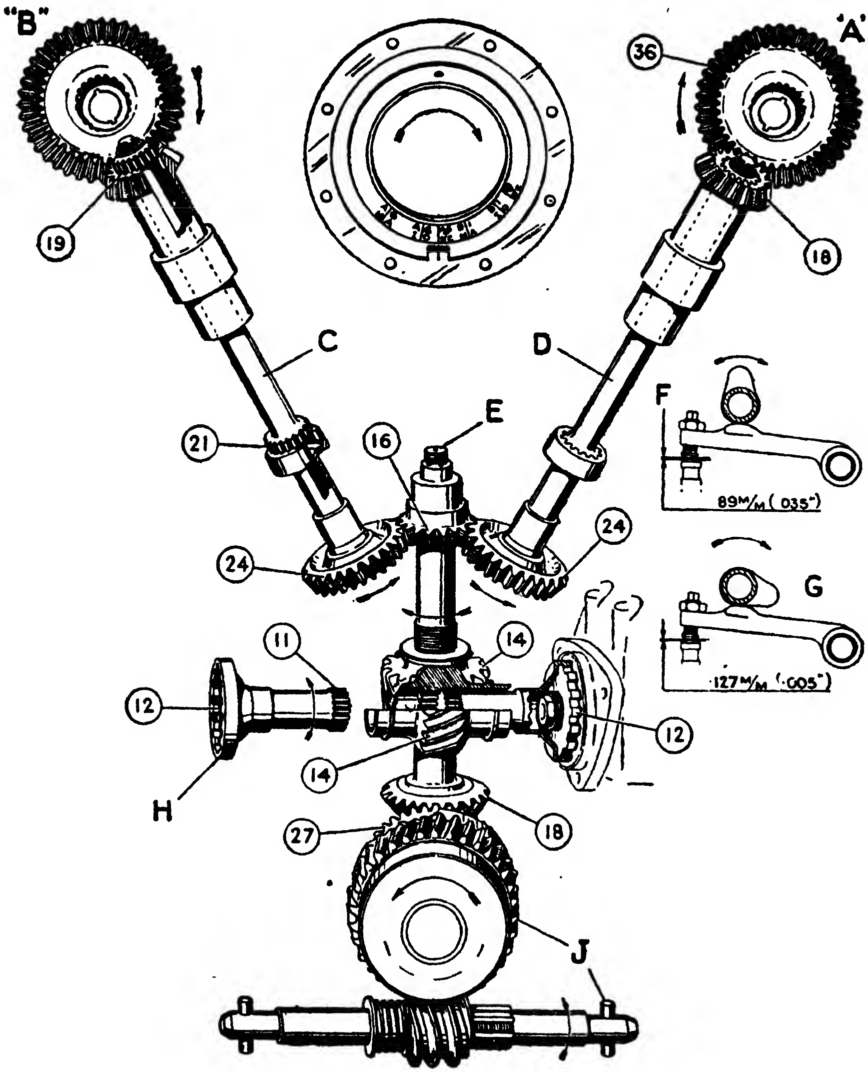


Fig. 23.—Diagrammatic Layout of Timing Gear.

mentioned above carrying the main driving bevel wheel (Fig. 22). The worm is mounted beneath on a splined transverse shaft and is brought into mesh with the worm-wheel by means of a striking lever and the rotation of the starting handle. When the engine starts, the worm-wheel overrides

the worm and throws it out of mesh ; it is held so by a spring on the worm-shaft. If the engine backfires, the gears remain in mesh and the friction clutch slips to relieve the stress on the gear teeth.

The operator is therefore safeguarded from any danger as the worm gear mechanism is not reversible, *i.e.*, it is not possible to turn the worm and handle by rotation of the crankshaft.

Timing Gear (Fig. 23) is included at this point to show the layout of the camshaft and magneto drives. The method of re-timing the engine is referred to on page 368.

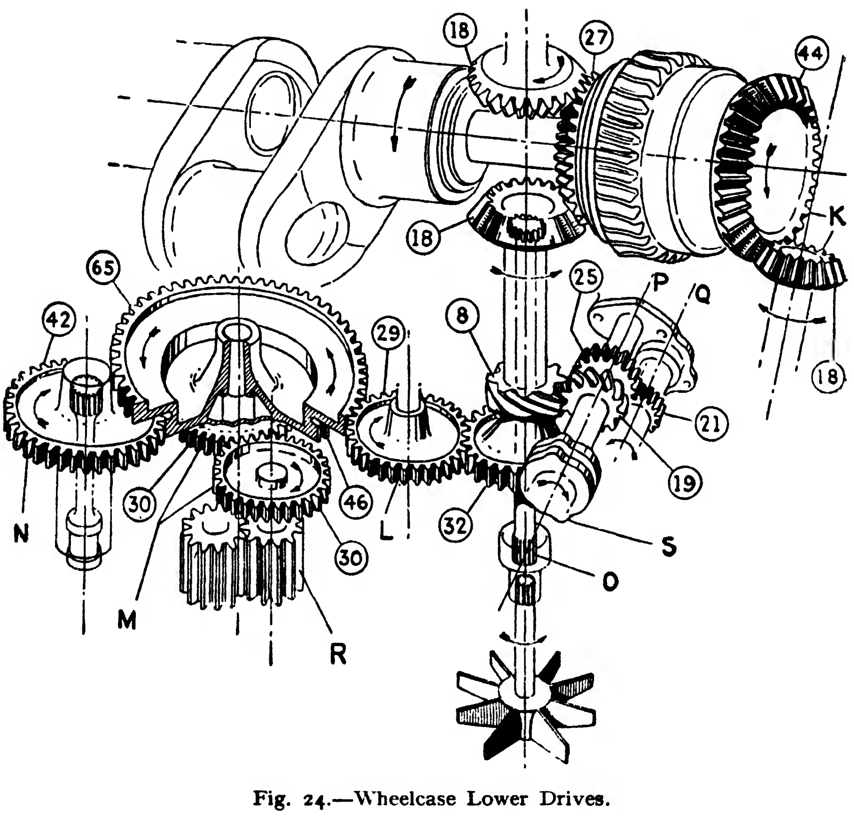


Fig. 24.—Wheelcase Lower Drives.

Lower Camshaft Drive.—This consists of a combined vertical shaft and bevel pinion which meshes with the main driving bevel wheel on the top side (for general arrangement of gearing see Fig. 23). The shaft has keyed to it at the upper end a bevel pinion which meshes with the bevel wheels on the inclined drives to the camshafts. Keyed to the shaft in mid-length is a skew gear which meshes with a similar gear on a transverse sleeve to which the magnetos are coupled. The coupling (11 splines in the sleeve and 12 on the magneto flange) forms a vernier whereby the ignition timing can be set to within 0·9°, or less, of the desired point.

Lower Driving Shaft.—This vertical shaft (shown in Figs. 24 and 25) has a bevel pinion at its upper end which meshes with the main driving bevel wheel on its underside. The shaft has a skew gear which meshes

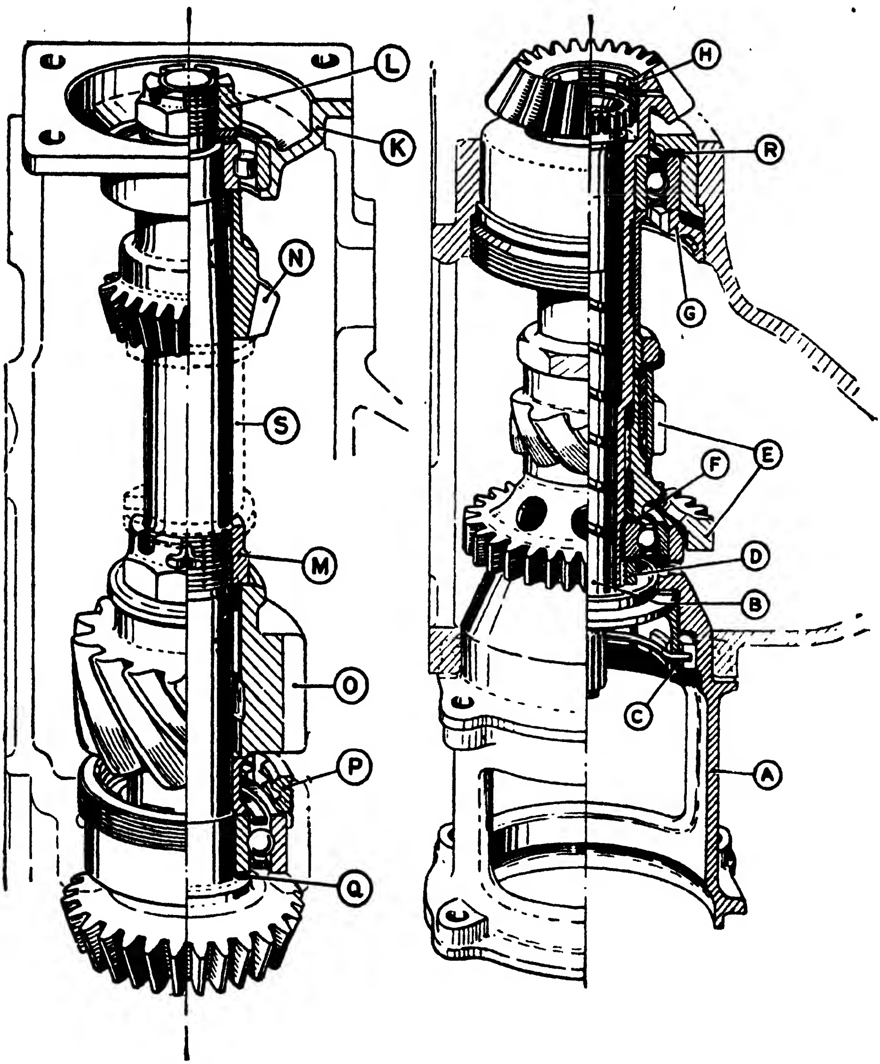


Fig. 25—Wheelcase Upper and Lower Drives.

with a similar gear on the transverse shaft which carries the gun gear cams, and a spur gear wheel, which, via an idler wheel, drives the oil pumps situated in the crankcase lower portion. The drive to the water pump is conveyed by a central shaft splined to the lower driving shaft.

Water Pump (Fig. 27).—This is mounted co-axial with the lower driving shaft and rotates at one and a half times engine speed. It is of the usual straight vane centrifugal type, arranged with two outlets, which connect by pipes to the inlet branch of each cylinder block. An auxiliary branch pipe from the carburettor leads into the inlet branch of the pump, and a

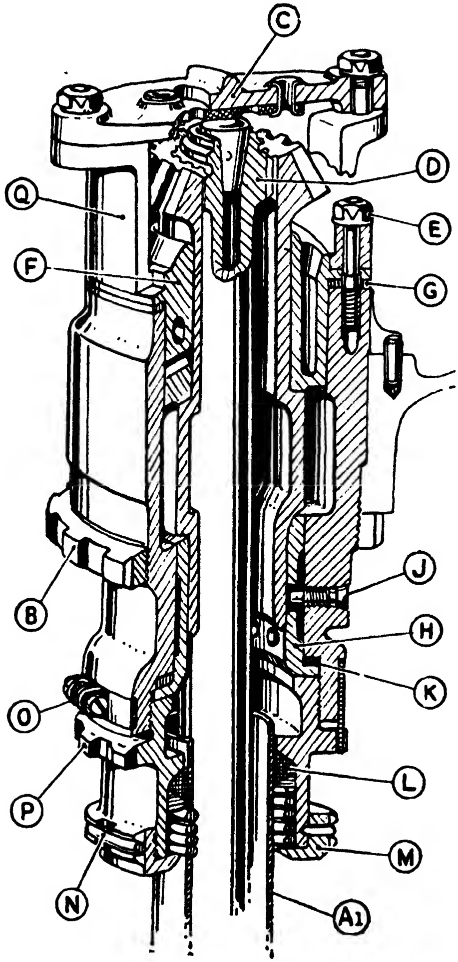


Fig. 26.—Sectional View of Upper Camshaft Drive.

screw-down grease cup is provided to lubricate the pump spindle, which is furnished with a hand-adjustable packing gland to prevent water leakage. The gland nut is locked against slacking back by a ratchet and spring. A drain cock is provided in the pipe line from the carburettor jacket.

Water Connections. (Fig. 28).—A pipe leads from each outlet branch of the water pump to an elbow fitted low down on the exhaust side of the

cylinder block between Nos. 5 and 6 cylinders. At this point there is a 13/16th in. dia. restriction washer to counteract reversal of flow of water, which is apt to occur when the engine is quickly throttled back.

The water, from these points, flows around and between the cylinder liners and heads, and leaves each block by three outlets, one forward, one rearward, and one in the centre. The forward outlets are each fitted with a vent cock and the rearward elbows each have a ½ in. dia. restriction joint washer fitted between them and the cylinder blocks. These outlets are connected for each block by a pipe lying just above the inlet valve ports, both pipes leading back, independently, to the cooling system of the

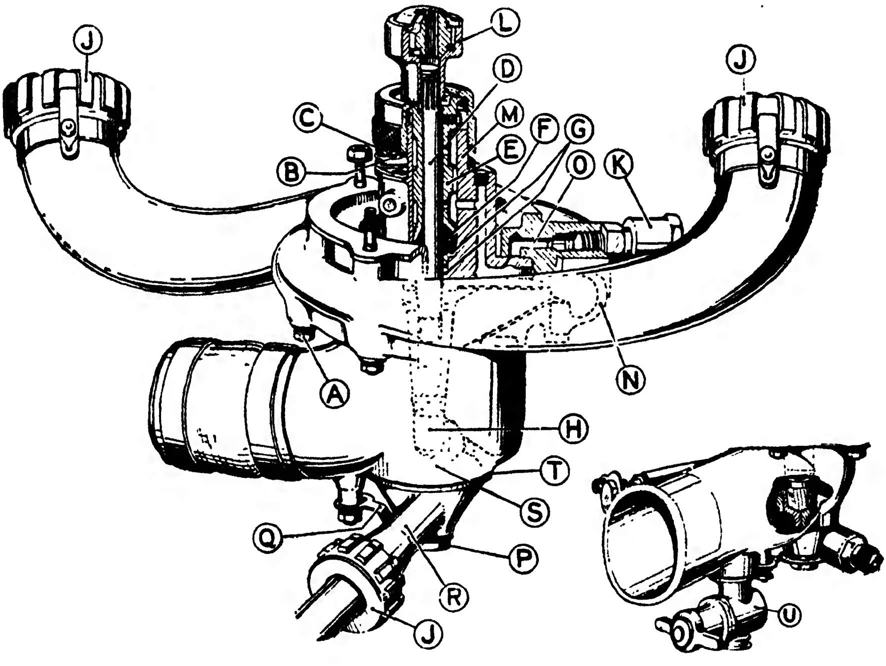


Fig. 27.—Section of Water Pump.

aeroplane. The " B " side pipe is fitted with a pocket for the bulb of a radiator thermometer, the corresponding point on the "A" side pipe having a branch pipe leading to a fitting integral with the controls bracket on the back of the supercharger casing, from which another pipe leads to a water jacket on the carburettor. Finally, a pipe leads from the base of the carburettor back to the auxiliary inlet branch on the water pump. The main inlet water branch connects to the aeroplane cooling system.

Gun Gear.—The transverse shaft mentioned on page 299 is fitted with a skew gear of nineteen teeth in engines with airscrew reduction gears of 0·553 ratio, or with twenty-two teeth in engines with gears of 0·477 ratio. This ensures that the gun gear cams, which are mounted on this shaft, rotate at airscrew speed (see Fig. 24). The cams, which are mounted on a sleeve splined to the port end of the shaft, are serrated (sixty serrations)

to the sleeve which can be withdrawn off the end of the shaft, for timing purposes, by undoing the end nut. The aperture in the wheelcase is closed

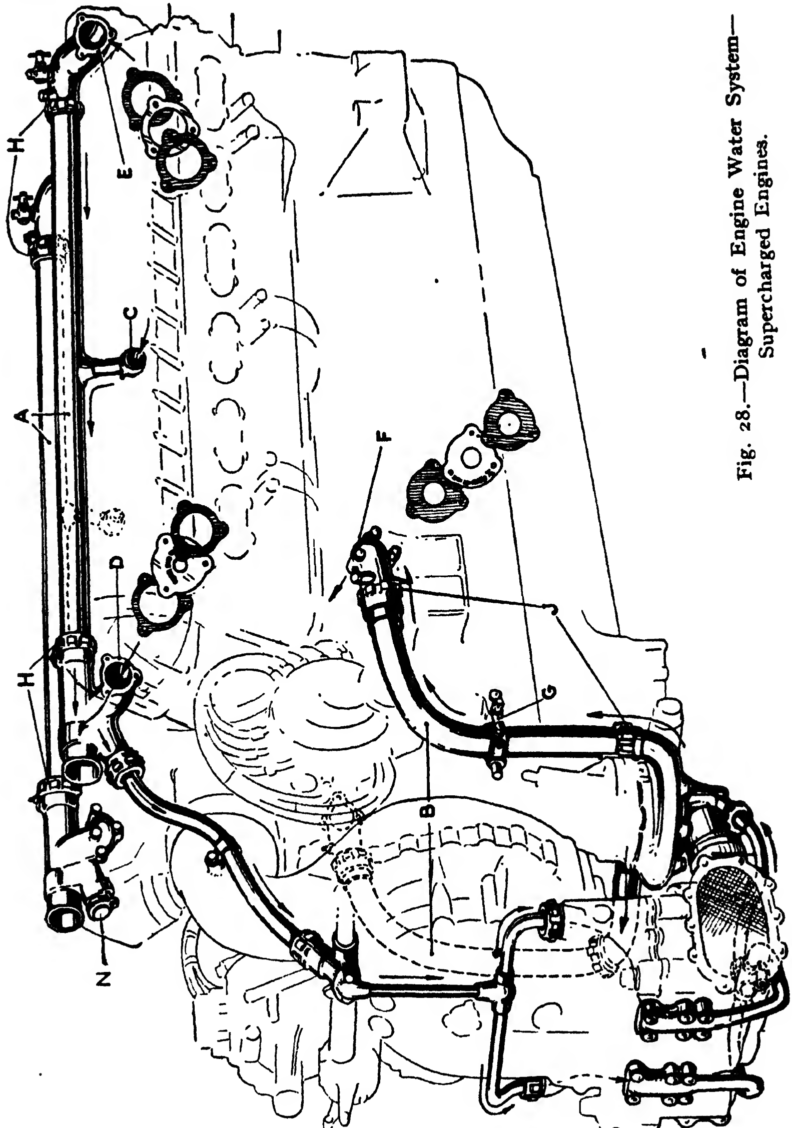


Fig. 28.—Diagram of Engine Water System—Supercharged Engines.

by an aluminium end cover which is retained by a flat spring pivoted to an adjacent standard.

Fuel Pump. (Fig. 30).—This is bolted to a facing on the starboard side of the wheelcase and is driven by spur gearing from the transverse shaft

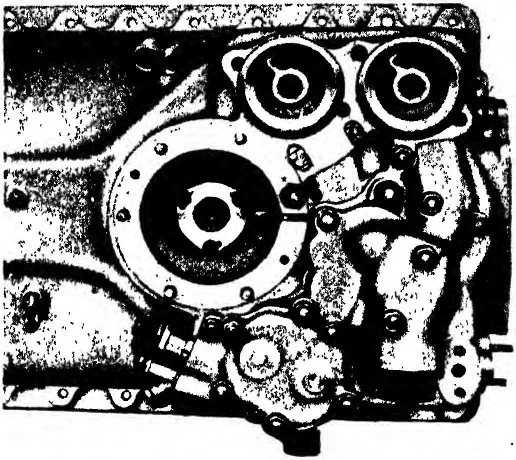


Fig. 29.—Inverted view of Crankcase Lower Half, showing Oil Pumps, Suction Filters, and Facing and Drive for R.A.E. Compressor.

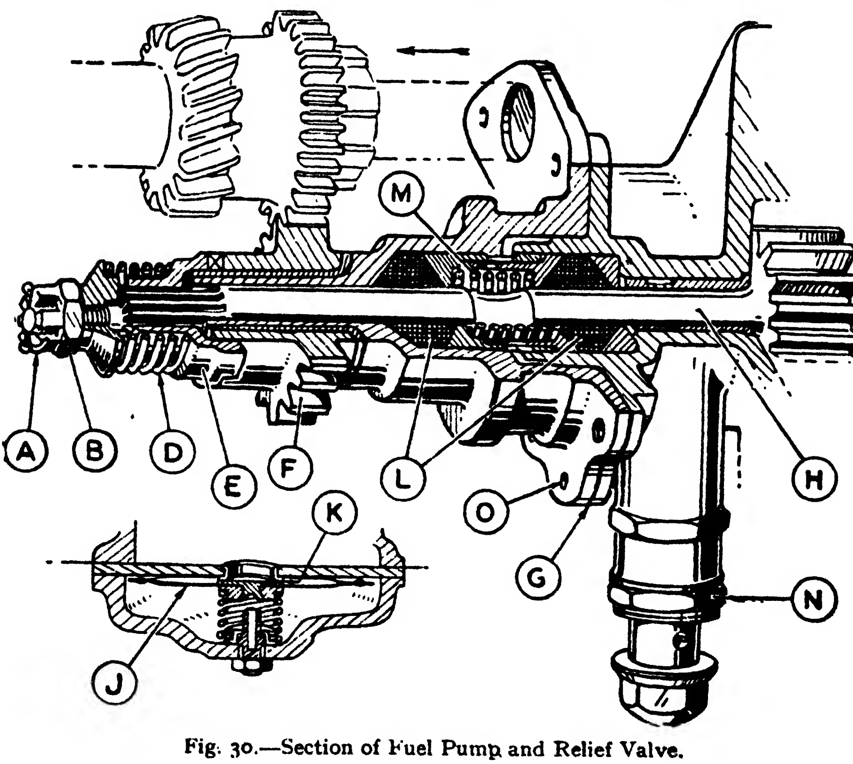


Fig. 30.—Section of Fuel Pump and Relief Valve.

driving the gun gear cams. The pump is of the gear type and has a relief valve on the pressure outlet side which by-passes fuel, in excess of the requirements of the carburettor, to the suction side. The pump driving spindle is fitted with spring-loaded glands and high-pressure lubrication

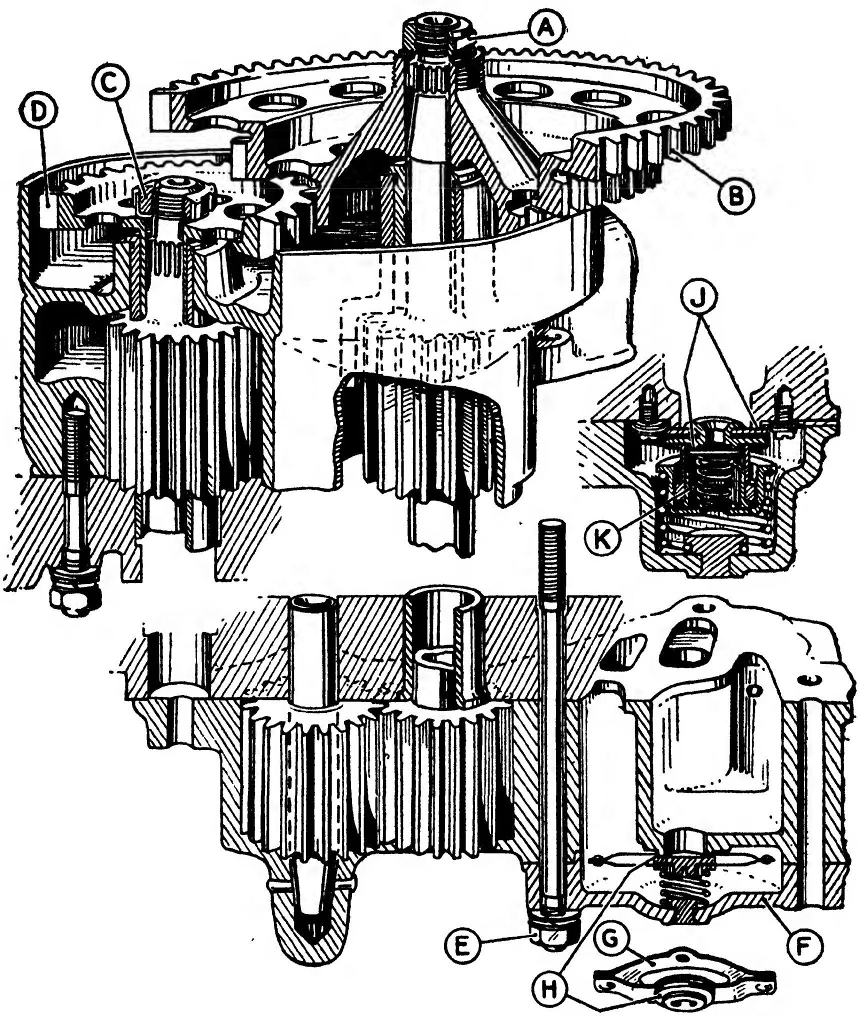


Fig. 31.—General view of Oil Pumps and Relief Valves.

to obviate leakage of fuel into the wheelcase. A blanking plate, with dummy union for the oil pipe, is fitted to the aperture for the fuel pump when the latter is not supplied with the engine.

Scavenge Oil Pumps (Fig. 31).—These are fitted to a facing on the floor of the rear sump in the crankcase lower portion and driven from a vertical shaft geared to an idler wheel, as stated previously.

Two scavenge pumps are employed, side by side, and geared together at their upper end by gears splined to their respective shafts. The drive from the idler is taken by the top gear of a cluster of three, splined on to the starboard or rear pump. The middle gear drives the air compressor and the lower gear the other scavenge pump.

Two scavenge filters are bolted to adjacent facings lying fore and aft on the port side of the rear sump floor. The filter gauzes can be withdrawn for examination and cleaning after removing the caps beneath, which are bolted to the underside of the sump. The filters are arranged so that oil is drawn by the scavenge pump from the crankcase or sump through the filters and then discharged through the oil cooler to the tank.

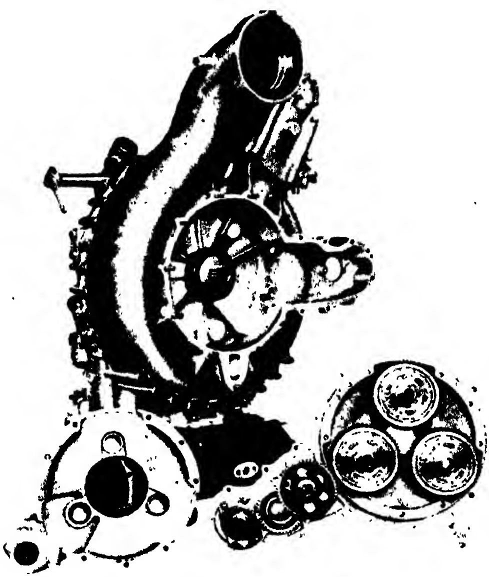


Fig. 32.—Supercharger Assembly and Drive.

The oil from the rear sump is conveyed to the rear pump and, passing round the gears, is discharged into a duct between the two pumps. The oil from the forward filter passes to a duct between the two pumps and is carried round the gears of the front pump to a duct, connected by an S passage, to the outlet from the rear pump. The combined discharge is led to the outlet union on the starboard side of the sump.

Pressure Oil Pump.—The pressure pump and relief valve casings are bolted together, and to a facing on the underside of the crankcase lower portion, beneath the scavenge oil pumps. The driving gear is formed integral with the vertical shaft of the rear scavenge pump. Oil from the tank enters the pump by a union on the starboard side of the engine and passes round the pump gears to a forward-facing outlet on the starboard side of the pump. A port in the wall of the delivery passage communicates

with the pressure relief valve casing; the high-pressure relief valve is set to lift upwards at 50 to 70 lbs./sq. in.

The high-pressure relief valve has undergone several modifications since its inception, but on current Kestrel engines it is a duplex valve, the main portion of which regulates the high-pressure supply, and the central auxiliary valve with its light spring, while lifting to maintain the low-pressure supply,

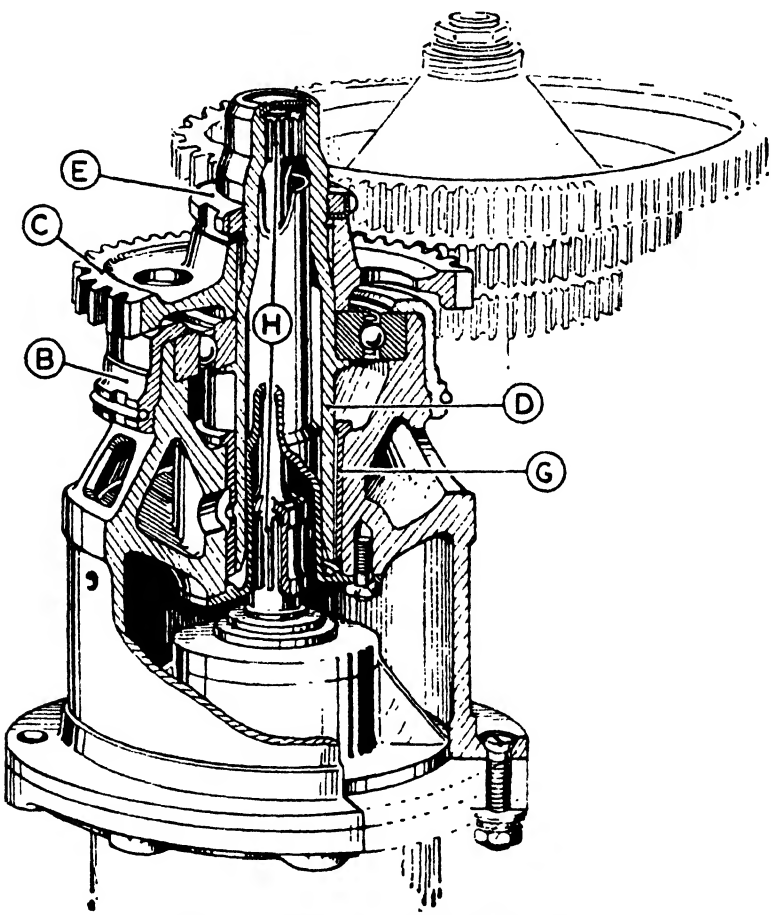


Fig 33.—Crankcase Air Compressor Drive.

also serves to counteract oil draining out of the low-pressure pipe lines when the engine is stationary, and in this way ensures a primed low-pressure system on restarting the engine. The latest modification restricts the lift of the main valve to 0·030 ins. The oil which is discharged from this relief valve passes to the underside of the low-pressure relief valve; this valve is set to lift at 4 to 10 lbs./sq. inch. Oil discharged from this relief valve returns to the crankcase.

Low Pressure Air Compressor Drive (Fig. 33).—A facing is provided on the crankcase lower portion for a low pressure air compressor of the vane type. This is driven from a spur wheel meshed to the compound gear by which the oil pumps are driven, and the speed of rotation is 0·809 times engine speed. When the compressor is not fitted, the facing of the aperture is blanked off by a cover plate.

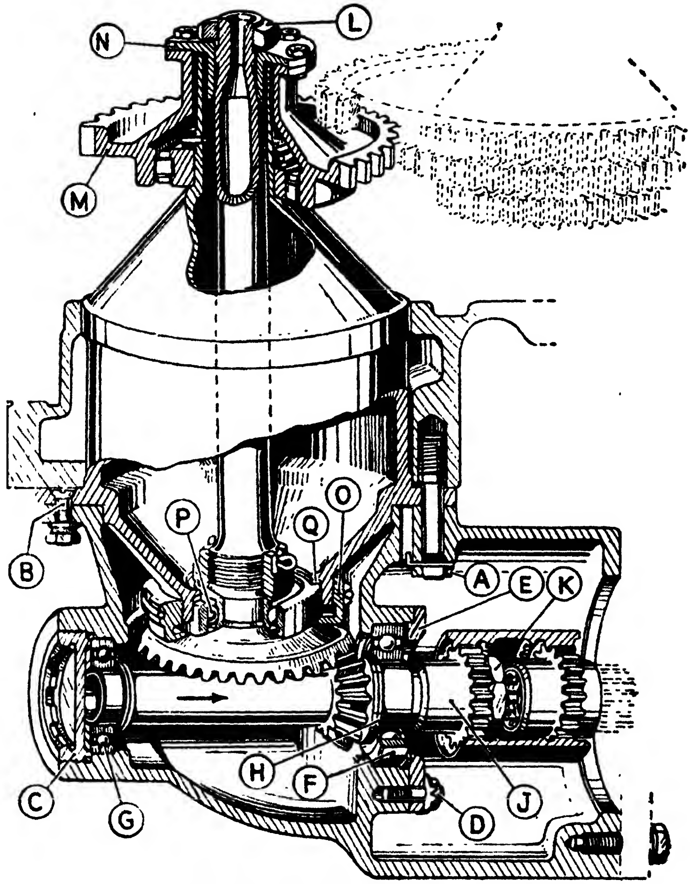


Fig. 34.—Sectional view of Vacuum Pump Drive.

Vacuum Pump Drive.—As an alternative to the low pressure air compressor mentioned above, a vacuum pump may be driven at 1·732 times engine speed by means of a right angle bevel drive unit, shown in Fig. 34. This unit consists of a vertical shaft having a gear at the upper end, meshing with one of the oil pump gears, similar to the compressor drive, but having a bevel gear at its lower end. The vacuum pump is driven through a splined coupling by a horizontal shaft, having a bevel pinion which meshes with the gear on the vertical shaft.

Supercharger (Fig. 32).—The supercharger consists of a centrifugal blower mounted co-axial with the crankshaft at the rear of the engine, and arranged to draw its air supply through the carburettor situated beneath it. The aluminium alloy impeller has radial vanes and is driven

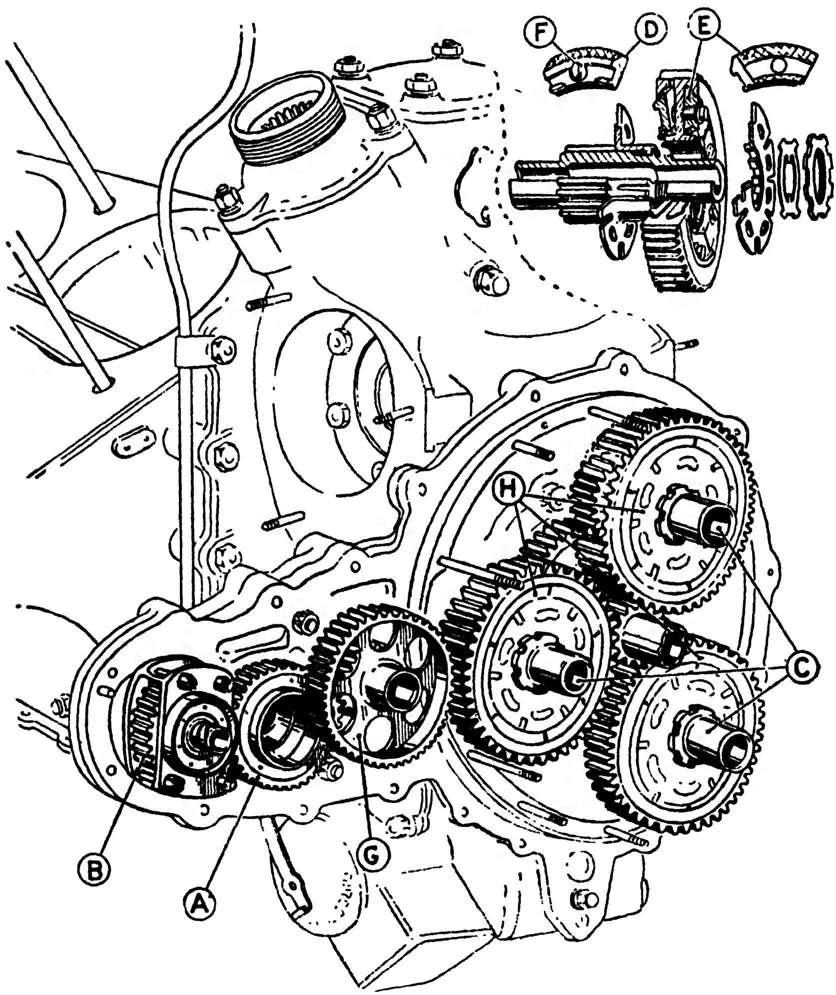


Fig. 35.—Supercharger and Generator Drive Gears with Casing Removed.

from a gear at the end of the spring drive hollow outer shaft by a trio of compound wheels, each of which meshes with the pinion on the impeller spindle. The ratios of the impeller speeds to engine speed are as follows :—Series IV., V., VI., 8·82 : 1 ; Series VII., VIII., IX., 6·92 : 1 ; and Series XIV., XV., XVI., 9·41 : 1.

The compound gears each incorporate an automatic clutch which serves to equalise the loadings on the gear teeth and to protect the gearing against damage, due to the inertia of the impeller on sudden acceleration or retardation of the crankshaft. The rim of the gear wheel is free to rotate on the hub. The hub has radially directed bronze segments which are pressed against the rim of the gear wheel by light springs, and thus impart the drive by frictional contact. The bronze segments are held between guide plates, and the drive is transmitted through pegs rivetted into the segments which are free to slide in slots in the guide plates. This frictional contact is intensified by the centrifugal force which the segments acquire when the hub is rotated. The centrifugal force varies as the square of the speed, and since the torque required by the supercharger varies at a like rate, it is possible to ensure that at any speed the maximum torque which the clutches can transmit exceeds the requirements of the supercharger by a fixed margin. During violent acceleration or retardation of the crankshaft, when the torque due to the inertia of the impeller with a rigid drive would be considerably in excess of the normal driving torque, the clutches slip and relieve the gearing of excessive loads.

The supercharger casing bolts to the rear face of the wheelcase, and the elbow for the connection to the induction manifold is integral with the upper part. The control bracket is attached to the rear of the casing and the boost control to the port side. The casing also extends to the port side to accommodate the train of gears to the generator as shown in Fig. 35.

Generator Drive.—The flexible drive to the generator can be brought out of the casing in either the forward or aft directions to suit various installations. Whichever aperture is not utilised for the drive is closed by means of a blanking plate. The flexible drive casing is furnished with a lubrication nipple.

Controls (Fig. 36).—The control shaft is borne in bushed brackets on the rear of the supercharger casing. One lever is pinned to each end of the shaft to convey control to the magnetos by adjustable forked links. The port lever has an intermediate pin for the forked adjustable link coupled to the lever (K) of the atmospheric change-over valve of the boost control. The linkage to the magneto is arranged togglewise to give 2° retardation from full advance for full throttle openings.

Next in order from the port end of the shaft and also pinned thereto is a lever which carries a bowed link and adjustable ball-and-socket connection to the lever (E) of the accelerator pump.

Next comes the lever (F) which is coupled to the throttle lever of the carburettor by a bowed and adjustable forked link. This lever is keyed to a bevel gear wheel (see also p. 325 and Fig. 47) which can rotate on the control shaft. The throttle lever works between adjustable stops (D) arranged just above the carburettor as shown. Arranged about the bevel gear is a split casing, bearing in its joint faces two diametrically disposed bevel pinions. The casing also enshrouds a second bevel wheel which is meshed to the first wheel through the bevel pinions, the whole forming a differential gear. The casing is bushed to rotate on the bosses of the two bevel wheels. The cross shaft through the bevel pinions is pinned to the control shaft.

Bolted to the differential gear casing is the lever (L) which connects by linkage to the pilot's throttle control in the cockpit. Keyed to the

second bevel wheel which, incidentally, is free to rotate on the control shaft, is a lever (N) which connects, by a forked adjustable link, to the relay piston of the boost control.

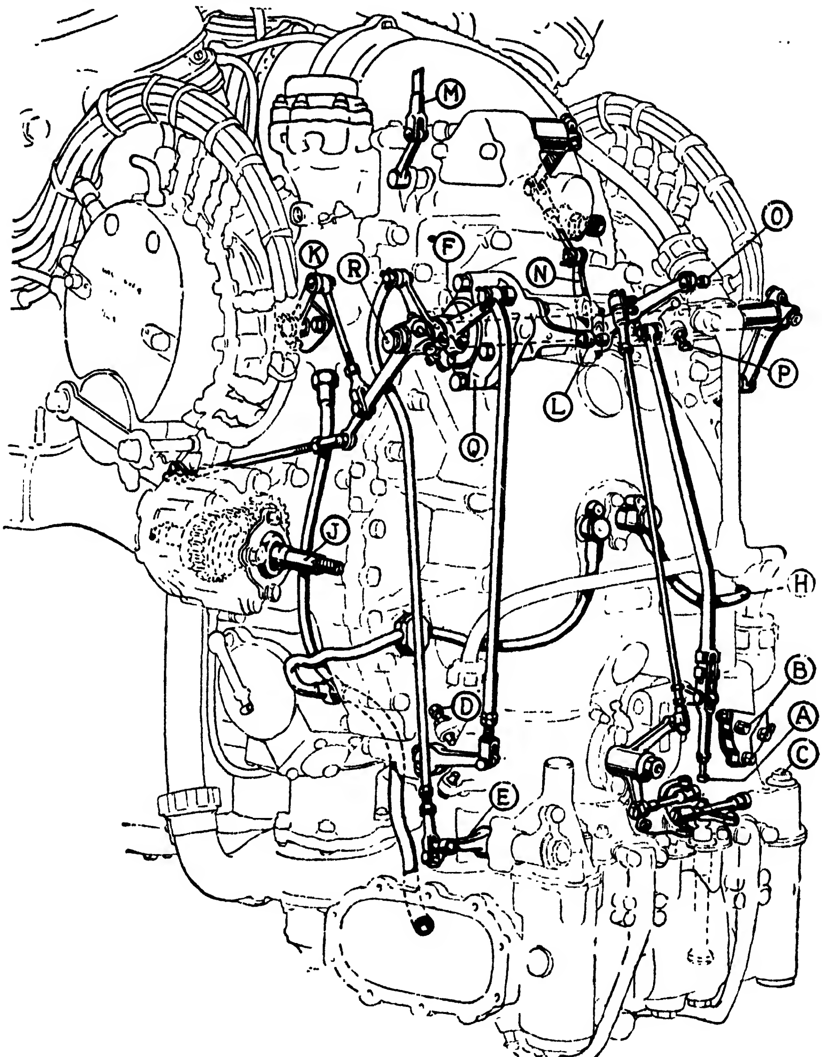


Fig. 36.—Engine Controls—Supercharged Engines.

The next lever (O) which is bushed to rotate on the control shaft, connects at the outer end with the linkage to the pilot's mixture control in the cockpit. It has an intermediate connection for a link to a bellcrank lever, working between adjustable stops, which couples to the interconnected pair of mixture control valves. Nearer the axis the lever has a

lug carrying an adjustable stop which comes in contact with the short lever of an adjacent sleeve which is pinned to the control shaft, and so ensures that the mixture control is brought back to normal as the throttle is closed. The sleeve also has an integral short lever which links up to an adjustable plunger (A) which actuates an enrichment device in the carburettor. Finally, the sleeve has an arm which swings into the path of an adjustable stop (P) located in the starboard bracket bearing the control shaft which fixes the throttle opening for maximum take-off boost.

It will be seen, therefore, that magneto controls, atmospheric valve, accelerator pump, pilot's throttle control and enrichment device, all move in unison, while the throttle valves and boost control work on opposite sides of the differential bevel pinions. Thus with the pilot's throttle control stationary, the boost control can operate the throttle valves through the differential gearing.

Induction System and Priming System (Fig. 37).—The carburetted mixture passes out of the two chokes into the throttle barrels and thence to the supercharger, whence it is delivered by a single outlet to the induction manifold, which has four branches, each delivering to a group of three cylinders. Each branch of the induction pipe is furnished with a priming orifice (M) by which fuel, in the form of a mist, is sprayed towards the inlet valves by the action of a hand-operated priming pump during starting operations.

Volute Drain (Inset Fig. 37).—The supercharger casing (P) has a drain hole at its lowest point, whereby fuel which tends to accumulate during cold idling conditions is led away and redistributed to the priming orifices in the induction manifold. This is accomplished by a venturi (Q), situated on the top of the port air intake, consisting of two nozzles arranged end to end with a small clearance, arranged in a cylindrical socket which receives the drainage from the supercharger. The lower nozzle is open to the air intake, the upper one connects by a flexible tube to the priming orifices. The result of this arrangement is that at low throttle openings when the depression in the induction manifold is low, air from the intake flows through the venturi, picks up the fuel drained from the supercharger and conveys it to the vicinity of the priming orifices to discharge.

Lubrication System.—Lubrication is on the dry sump principle, there being two scavenge pumps working in parallel to drain the sump, and one pressure pump to feed the engine. A diagrammatic sketch of the lubrication system is given in Fig. 38 (Folder).

The pressure pump receives oil from the tank and delivers it by an external pipe to a fitting on the port side of the engine; this fitting has adaptors for a pressure gauge and a thermometer. The oil is distributed from this point to each of the seven crankshaft bearing caps whence, after lubricating the journals, it passes into the interior of the crankshaft to the crankpins, so lubricating the connecting rod big-end bearings. The oil released from these bearings is distributed within the crankcase and the cylinder bores, and forms the splash element of the system whereby the pistons, gudgeon pins and connecting rod small ends are lubricated.

A branch pipe conveys high-pressure oil to the fuel pump for lubrication of the white metal bushes, and the oil passes through a non-return valve before reaching the pump. If this pump is not supplied with the engine, a blanking plate furnished with a dummy connection for the oil pipe is

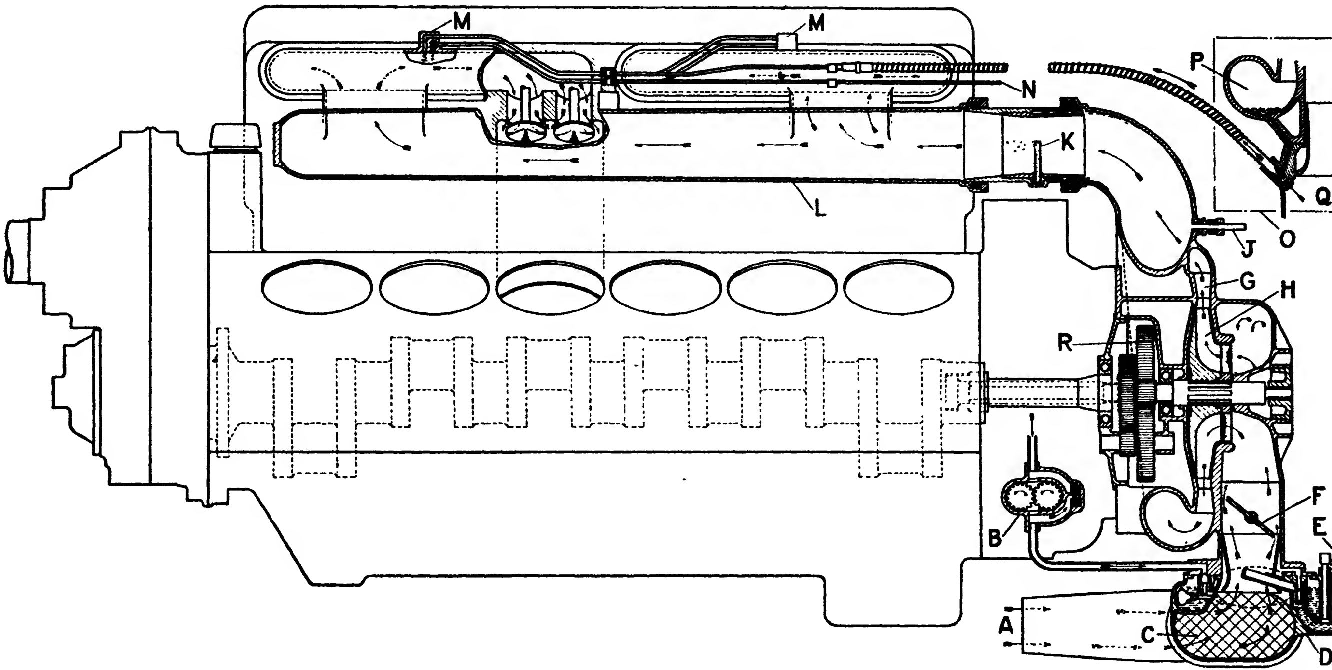


Fig. 37.—Diagrammatic Lay-out of Supercharger System (One Cylinder Block and Connecting Rods Removed).

A. Air Intake to Carburetters.
B. Fuel Pumps and Relief Valve.
C. Filter Gauze.
D. Carburetters.
E. Main Jet or Mixture Control.
F. Throttle Valve.
G. Supercharger Vane Deflector Ring.
H. Supercharger Impeller.
J. Boost Gauge Connection.
K. Re-distribution Pipe for Condensed Fuel.
L. Main Distribution Manifold.
M. Priming and Volute Drain Discharge Nozzles.
N. Main Supply Pipe from Priming Pump.
O. Scrap View showing Volute Drain System.
P. Supercharger Volute.
Q. Carburettor Intake.
R. Balanced Slipper Gear for Supercharger Drive.

fitted. A duct in the high-pressure system leads to the high-pressure relief valve, which regulates the pressure to from 50 to 70 lbs./sq. in. The oil which passes through this valve, either due to its lift or through the metering hole in the centre of the valve, forms the low pressure supply which feeds the camshaft and rockers, reduction gear, and electric generator drive. The camshaft drives and timing gears are lubricated by oil which drains back to the crankcase through the camshaft drive housings. A relief valve is fitted in the low pressure system, regulating the pressure to from 4 to 10 lbs./sq. in. Excess oil is returned to the rear sump in the crankcase.

Two scavenge pumps are provided, one drawing oil from the front sump through a forward filter and the other dealing with the oil in the rear sump through a similar filter. Both pumps deliver into a common duct leading back to the tank. The filters on the suction sides of the pumps are detachable downwards through the bottom of the sump for cleaning.

An outlet is provided at the front end of the crankcase, just behind the upper portion of the joint face for the reduction gear cover.

This outlet is fitted with an elbow with union and pipe by which any discharge is conveyed to the oil tank. The fitting of a closed form of breather obviates discharge of oil into the engine bay during aerobatics or inverted flying.

GENERAL DESCRIPTION.

Unsupercharged Engines.

With the exception of certain inevitable differences, such as the wheelcase and induction system, the unsupercharged engines are identical with the supercharged types. All major items are interchangeable with the exception of those referred to below.

Pistons.—The pistons differ from the supercharged type in that they provide a compression ratio of 7 : 1, in place of 6 : 1. In general design they are similar to the ones previously described, having three compression rings, and one scraper ring at the bottom of the skirt.

Wheelcase and Gears.—The absence of a supercharger considerably simplifies the wheelcase. The drive for the auxiliaries and camshafts is taken from the rear end of the crankshaft by a spring drive, as before. The upper and lower vertical drives, driven from a bevel gear on the spring drive assembly, co-axial with the crankshaft, are practically unchanged, the water and oil pumps being driven by the lower vertical drive.

The generator, whose axis is at right angles to that of the crankshaft, is driven by a bevel gear on the rear end of the spring drive.

Spring Drive (Fig. 39).—The lay-out of the spring drive differs from that used on supercharged engines in that a friction damper is incorporated. Torsional oscillation of the crankshaft rear end is bound to occur to some degree which, in the case of the supercharged engine is almost completely isolated from the accessory drives by the combined effect of the flexible drive and supercharger impeller, with its high gear ratio and high equivalent inertia. It is the absence of the impeller which makes some other damping device necessary for the unsupercharged engine.

As before, a long slender shaft (L) is used, splined into the rear crankshaft journal with little or no backlash. The shaft is surrounded by a stiff, hollow guard shaft (B) also splined into the rear of the crankshaft without backlash.

At the rear of the spring drive shaft a flange (U) is splined and nutted to the shaft, transmitting the drive through splines on its outer edge to the outside of the friction damper housing, which is integral with a sleeve enclosing the hollow guard shaft. The sleeve is carried in a ball bearing at the rear end, mounted in the wheelcase casting, and has internal bushes

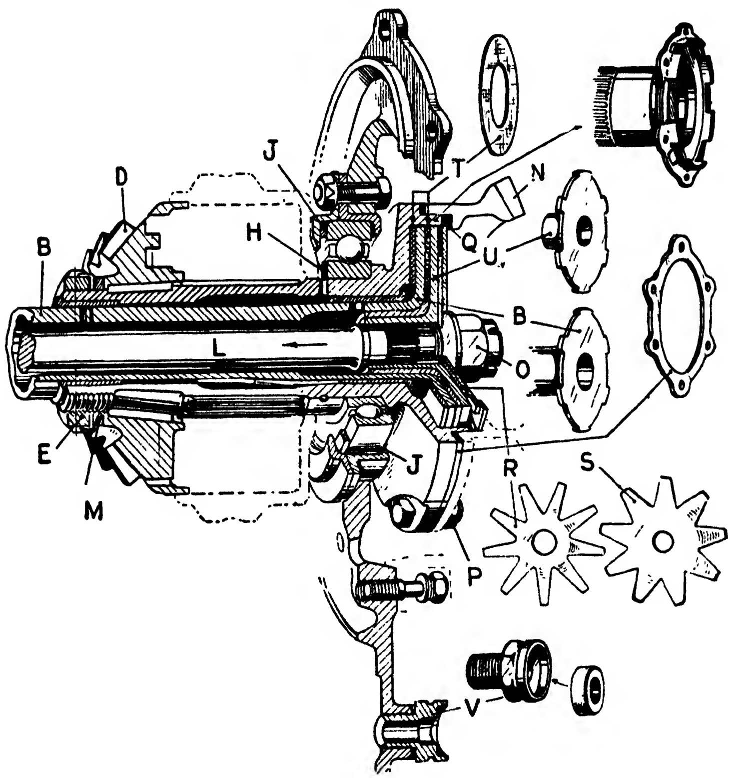


Fig. 39.—Friction-Damped Spring Drive—Normally Aspirated Engines.

at the front and rear ends bearing on the outside of the hollow guard shaft. The bevel wheel (D) for the upper and lower vertical drives, and the starter worm gear and clutch are mounted on the sleeve. The generator is driven from a bevel gear (N) bolted to the rear flange of the friction damper.

Under normal running conditions, the drive to the auxiliaries is transmitted through the spring drive shaft to the friction damper casing and thence to the sleeve and bevel gear. The friction damper consists of two discs of bakelised fabric (T) held in the housing by two star-shaped spring discs (R) and (S), tightened by the nut on the spring drive shaft. These discs have between them a flange formed integral with the rear of the

hollow guard shaft which is splined to, and rotates with, the crankshaft. The torque to drive the accessories causes a deflection of the spring drive

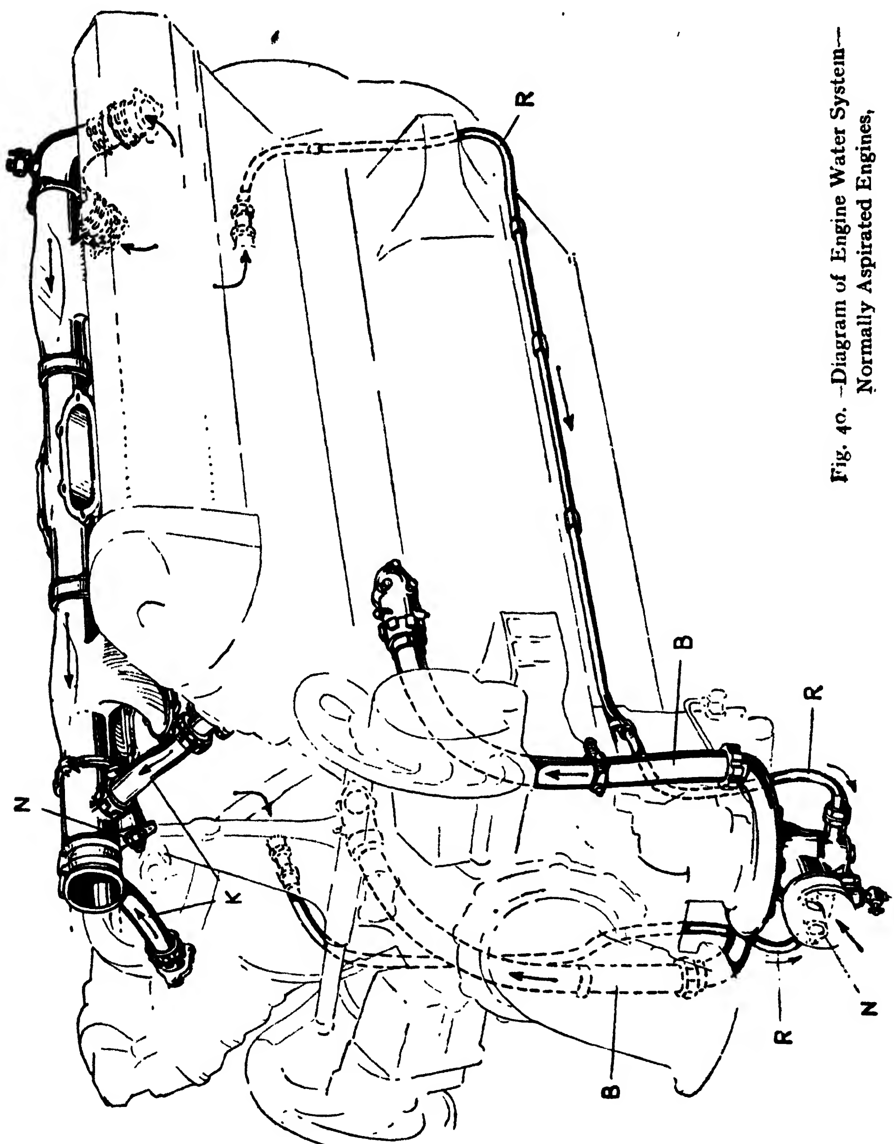


Fig. 40.—Diagram of Engine Water System—Normally Aspirated Engines.

shaft rear end relative to the hollow guard shaft, and the effect of friction between the discs is to damp out any oscillation between them.

The disc at the rear of the guard shaft, within the damper, also has

splines on its outer edge which mesh with splines in the damper housing, with considerable backlash. The spacing of the splines is such that all the backlash is in one direction, so that the splines on the disc do not engage until the spring drive shaft has twisted through an angle corresponding to its maximum safe torque. Thus in the event of over-loading or actual breakage of the spring drive shaft, the drive is taken by the guard shaft.

When starting the engine by hand, the drive is taken through the guard shaft, since there is no backlash in this direction of rotation.

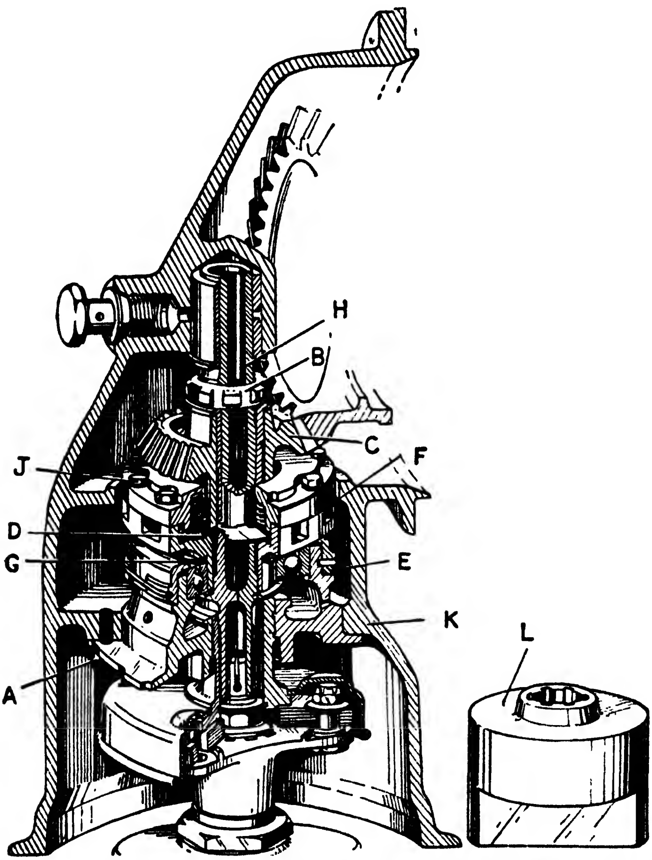


Fig. 41.—Electric Generator Drive—Normally Aspirated Engines.

Generator Drive (Fig. 41).—The generator is driven at twice engine speed by a bevel gear on the rear of the spring drive mechanism. This gear drives a pinion (C) mounted on a shaft at right angles to the crankshaft centre line and inclined at 22·5° to the port side of the lower vertical through the crankshaft centre line.

This drive shaft incorporates a friction clutch (F) to protect the gearing from excessive loading during sudden acceleration or deceleration, and

drives the generator at its lower end through a fabric disc type of universal joint.

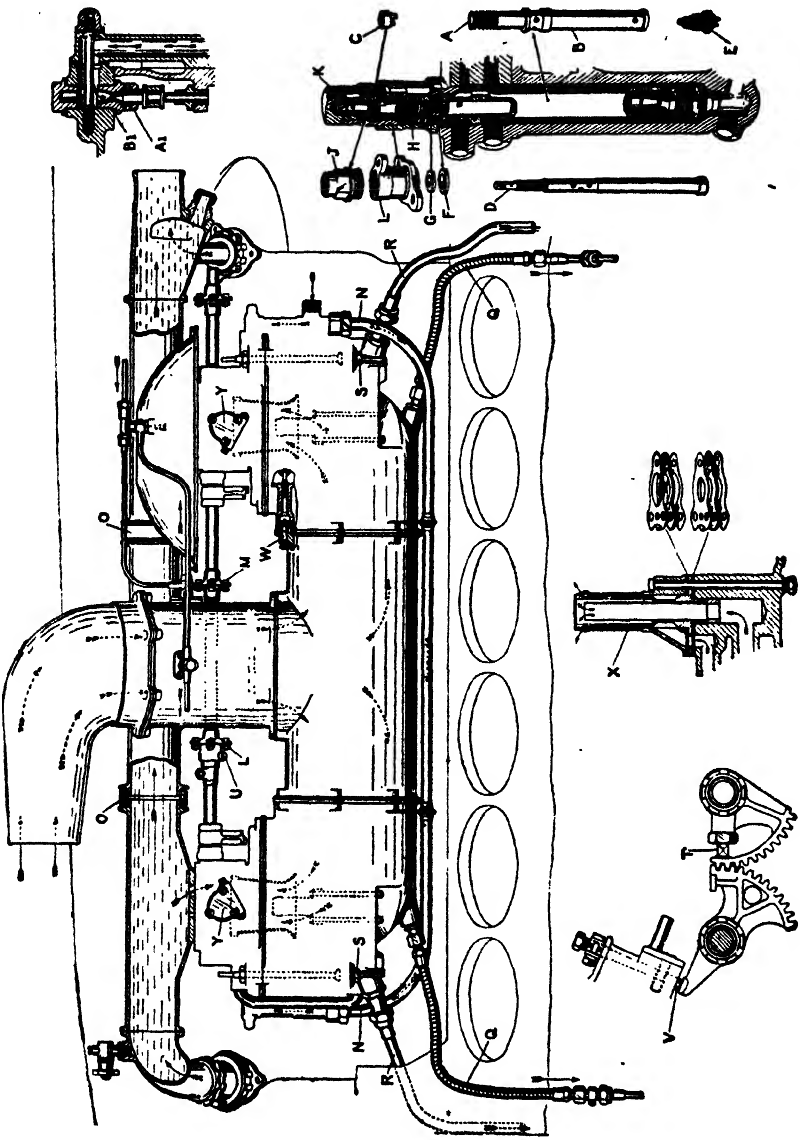


Fig. 42.—Diagram of Induction Manifold and Carburettors in the Vee—Normally Aspirated Engines.

The shaft is carried in a plain bearing at the upper end, lubricated by low pressure oil supplied by an external pipe. The lower end is supported by a ball-bearing, which also takes the end thrust. The bevel pinion is

mounted on a bronze bush on the shaft, to allow relative motion when the clutch is slipping. The clutch housing is splined to the drive shaft, and encloses two bronze discs (D) splined on their outer edges. A steel disc coupled to splines on the boss of the bevel pinion lies between the bronze discs, which are pressed together by springs, the tension of which is such that the clutch slips at approximately six times the maximum torque necessary to drive the generator.

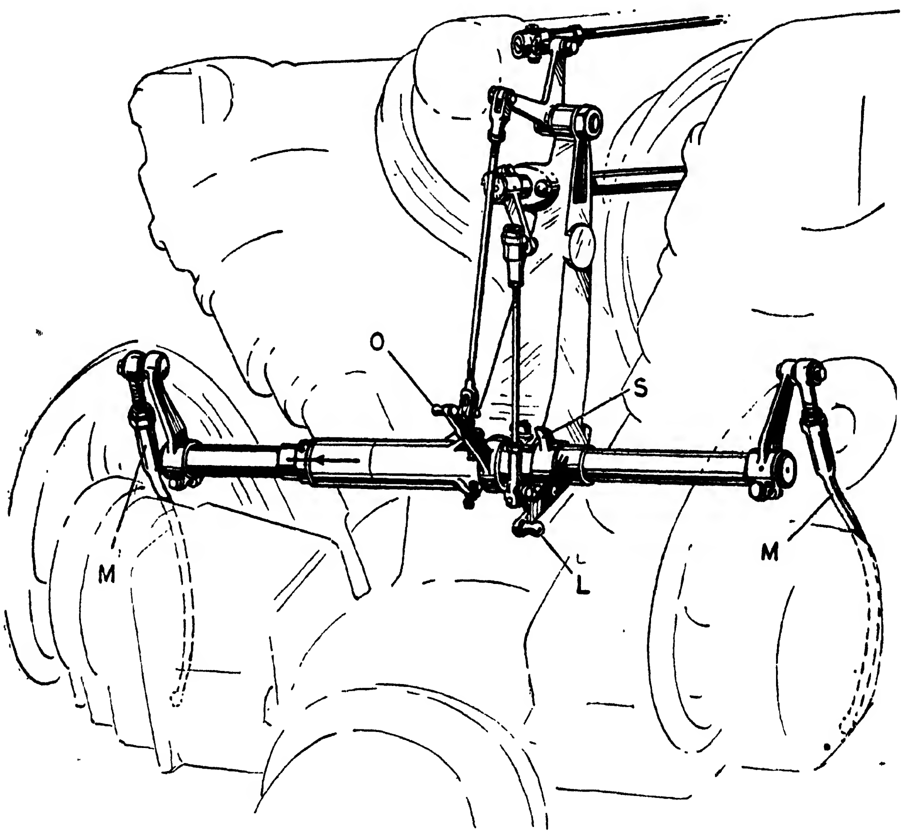


Fig. 43.—Engine Controls—Normally Aspirated Engines.

The generator has a spider attached to its spindle which carries the fabric disc and is driven from the spider splined to the drive shaft and free to slide axially. The latter has a square thread enclosed by a part of the housing, as an oil seal. The fabric disc is further protected from oil by a sheet metal casing.

Carburettors and Induction System (Fig. 42).—The two carburettors are situated fore and aft, between the Vee of the cylinder blocks, opposite cylinders No. 2 and 5 respectively. Each carburettor has two updraught

choke tubes placed laterally, and each choke supplies mixture to the three cylinders adjacent. Thus the starboard choke of the forward carburettor supplies mixture to cylinders A1, A2, A3, and the port choke of the rear carburettor to cylinders B4, B5, B6.

Two air intakes, situated side-by-side midway between the two carburettors, supply air to a central duct which leads fore and aft to the carburettors. Part of the cooling water outlet pipe from the cylinders is incorporated with the induction system, to provide heating to the elbow in the induction pipe above each choke tube.

For a description of the carburettors, see the special section with that heading (page 321).

Controls.—The controls consist of throttle and mixture controls, and inter-connection between the throttle and magneto controls.

The throttle control shaft is carried by a bracket attached to the top of the wheelcase, and lies transversely across the engine. The pilot's control is attached to a lever on the cross shaft, and the latter has a lever at either end connected to levers on the magneto cam rings. The levers are arranged to toggle at full throttle, and give 20° advance and retard, the timing being retarded for starting and slow-running.

The starboard throttles are operated by rotation of a longitudinal shaft in the axis of the two starboard throttle spindles, and the port throttle spindles are geared to the starboard ones by segments of a gear wheel. The longitudinal shaft is operated by a link and levers from the transverse shaft previously referred to and has three flexible joints, and an adjustment for synchronising the throttles.

The pilot's mixture control link works a lever mounted on a sleeve enclosing part of the transverse throttle control shaft. Rotation of this sleeve is converted, by an intermediate bell-crank lever, to fore and aft movement of a divided link which lies above the central water outlet pipe, passing above the two carburettors and operating the mixture control valves on each carburettor.

CARBURETTOR.

Supercharged Engines.

The carburettor is situated at the rear of the engine below the supercharger intake, the upper half of the carburettor being incorporated in the supercharger rear half and intake casting.

There are two choke tubes, side by side, and the two butterfly throttle valves above the choke tubes are mounted on a common spindle. The body of the carburettor surrounding the chokes is hot-water jacketted, the flow being from one top outlet pipe to the pump suction.

A mixture control, consisting of a valve by which the flow of fuel to the diffusers can be varied, enables the pilot to adjust the setting of the carburettor to provide the correct mixture at any altitude. Rapid "opening up" is ensured by an accelerator pump which injects fuel into the mixture stream when the throttles are suddenly opened, and an enrichment device is fitted to provide rich mixture for "take-off" or full throttle operation.

The detailed description of the carburettor which follows should be read in conjunction with Fig. 44.

Fuel is fed to a central float chamber between the two choke tubes and the level controlled by a float and needle valve.

The float chamber is vented to the annular spaces surrounding the choke tubes by two passages having a ball valve at the junction. For starting and slow-running a pilot jet and auxiliary diffuser, in the right-hand choke, are used. Fuel is supplied to the pilot jet (S) from the main diffuser well; a filter (R) being interposed to guard against blockage.

Suction at the throttle valve, with the valve almost shut, causes fuel to be drawn through the slow-running jet (S) and up the venturi tube above it. Air from the passage (U) is drawn into the fuel stream at the space between the jet and the venturi. To obtain the best mixture the screw (T) should be screwed down until the venturi touches the jet, and then screwed back a quarter to half turn. The rich mixture thus formed is delivered into the main air stream through an eccentric hole in the plug (V). This plug can be rotated by a worm gear, and forms the slow-running mixture adjustment. Turning the adjusting screw raises or lowers the point of discharge of the slow-running mixture, relative to the throttle valve. Raising the point of discharge above the throttle valve increases the suction in the venturi, and hence more fuel is discharged into the main air stream. Lowering the point of discharge reduces the suction, and the amount of fuel delivered, and so weakens the final mixture.

For part and full throttle operation, the air flow through the chokes causes a depression sufficient to bring the main diffusers into operation. Fuel to each choke passes through the main metering valves (E), and forms an emulsion with air which enters the hollow diffuser tube from the passage (F), and mixes with the fuel through holes in the wall of the tube. The mixture then passes to the main air stream through the diffuser nozzle (G).

When it is desired to alter the mixture strength, the two valves (E) may be rotated by the lever (D) thus altering the size of the orifice, and hence the fuel flow. The purpose and use of the mixture control is referred to under a separate heading (p. 322).

The mixture can be enriched for take-off and full throttle operation by the lever (P) which depresses the spindle of the starboard mixture control valve. The adjustment should be such that when the pilot's throttle lever is moved through the gate, the valve is depressed 0·030 in. or 0·040 in. from its seat. The additional fuel flow through the valve will then provide the necessary enrichment.

When the throttles are suddenly opened, there will not at once be sufficient air flow to cause the depression which is necessary to draw fuel from the main diffusers. The fuel level in the diffusers is half to one inch below the diffuser nozzles, and the inertia of the fuel has also to be overcome. For this reason the mixture tends to be too weak until the proper flow has been established, and this causes hesitation in opening up. To overcome this difficulty an accelerator pump (L) is provided, which sprays fuel into the port choke tube through the nozzle (N). The pump, consisting of a piston and piston rod working in a cylinder in the main carburettor casting, is connected to the throttle by the lever (J). Opening the throttle moves the piston downwards, forcing fuel into the discharge nozzle. To prevent fuel being drawn out of the nozzle (N), when the piston is stationary, the valve (M) is provided. This is normally closed by a light spring, but

[To face page 320

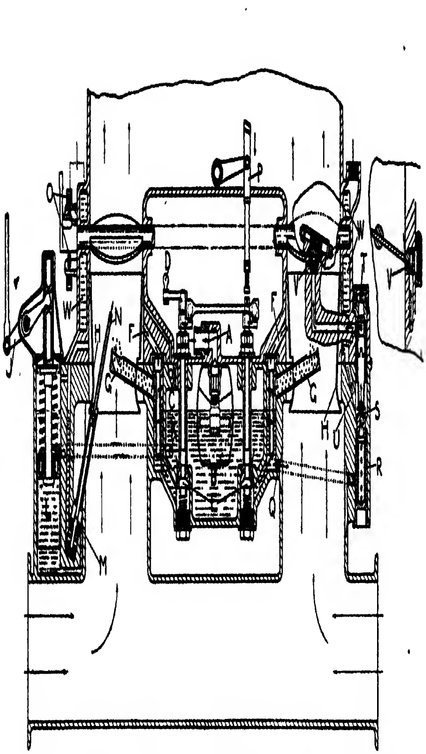


Fig. 44.—Diagrammatic Section of Carburettors—Supercharged Engines.

A. Fuel Inlet.
B. Float.
C. Float Chamber Air Vent and Ball Valve for Inverted Flying.
D. Mixture (Main Jet) Control.
E. Eccentric Varying Main Jet Flow.
F. Air Bleed to Main Diffuser.
G. Main Diffuser Nozzle.
H. Choke.
J. Accelerator Pump Control Lever (connected to Throttle Control Lever).
K. Fuel Supply to Accelerator Pump.
L. Accelerator Pump.
M. Spring Loaded Needle Valve.
N. Accelerator Pump Discharge Nozzle.
O. Main Throttle Operating Lever and Stops.
P. Mixture Strengthening Device (connected to Throttle Control Lever).
Q. Fuel Supply to Slow Running Jet.
R. Slow Running Filter.
S. Slow Running Jet.
T. Slow Running Mixture Adjustment.
U. Air Supply to Slow Running Device.
V. Slow Running Adjustment Plug.
W. Hot Water Jacket.

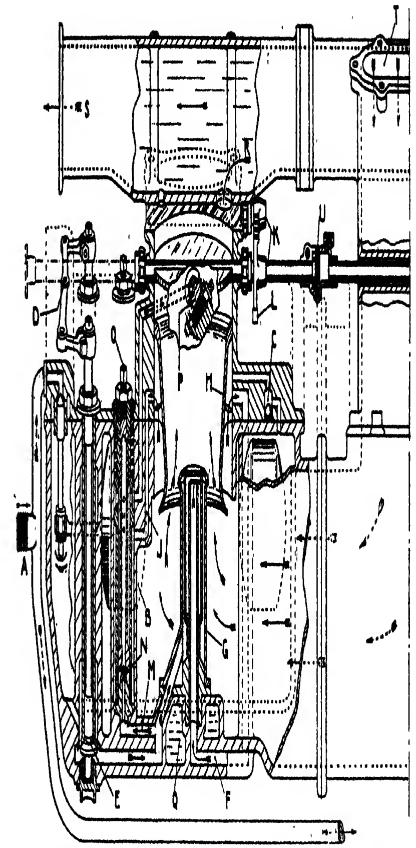


Fig. 45.—Diagrammatic Section of Carburettors—Normally Aspirated Engines.

A. Fuel Inlet.
B. Float.
C. Float Chamber Air Vent and Ball Valve for Inverted Flying.
D. Mixture (Main Jet) Control.
E. Eccentric Varying Main Jet Flow.
F. Air Bleed to Main Diffuser.
G. Main Diffuser Nozzle.
H. Choke.
J. Air Supply for Slow Running Device.
K. Main Throttle Shafts Coupled by Quadrant.
L. Throttle Stop Lever.
M. Fuel Supply to Slow Running Jet.
N. Slow Running Jet.
O. Slow Running Mixture Adjustment.
P. Slow Running Adjustment Plug.
Q. Hot Water Jacket.
R. Supply to Water Jacket.
S. Main Water Outlet Pipe.
T. Air Intake.
U. Worm Adjustment for Synchronising Front and Rear Throttles.

operation of the accelerator pump causes pressure to build up which compresses the spring and opens the valve. To prevent loss of fuel by slight or gradual movements of the throttle, the piston of the pump is provided with a disc valve held about 1/32 in. off its seat by a very light spring. The opening thus formed allows a small flow of fuel from one side of the piston to the other, but any rapid downward movement of the piston closes the valve and forces fuel through the nozzle (N). When the piston is raised, fuel from above the piston, which is supplied to the cylinder through the orifice (K) in the float chamber, passes to the underside of the piston through the open valve.

CARBURETTOR.

Naturally Aspirated Types.

The two carburettors are situated between the Vee of the cylinder blocks and each has two choke tubes placed transversely and operating as an independent unit.

Each choke has a diffuser, and slow-running system, and supplies three cylinders. No extra enrichment device or accelerator pump is fitted.

Mixture control is by a variable jet in the fuel supply to each diffuser and the four valve spindles are linked to a single control. The throttle spindles lie longitudinally, and the two spindles in each carburettor are geared together. The starboard throttles are connected by a common spindle, rotation of which opens or closes the valves, and operates the port throttles through the gearing. The carburettor bodies are water-jacketted, hot water being supplied from the outlet pipe above the carburettor and, after circulating through the jackets, the water passes from an outlet at the bottom to the suction side of the pump.

The following detailed description of the carburettor should be read in conjunction with Fig. 45.

Fuel to the two carburettors is fed to the Tee piece (A) where the flow divides to each carburettor, the level in each being controlled by a needle valve operated by two floats (B) on a common spindle, one forward of the choke tubes and the other to the rear. An air balance duct leads from the top of the float chamber to the space round the choke tube. For starting and slow running, fuel is supplied from the main diffuser, by the passage (M) to the jet (N). A venturi tube is situated above the jet, and fuel from the jet mixed with air (from behind the choke tube) which enters the annular space between the jet and venturi, passes up the venturi tube to an eccentrically placed orifice (P) in the cylinder, whence it is discharged into the air stream past the throttle valve.

The working of this slow-running system is identical with that described for the supercharged engine, except that the correct setting of the screw (O) is obtained by screwing the venturi tube one turn up from the jet, in place of the half to quarter turn for the supercharged engine carburettor.

For part and full throttle operation, the flow of air through the choke tube causes a depression which draws fuel and air through the main diffuser tube (G). Fuel from the float chamber passes through the metering valve (E) to the outer annular space in the diffuser and air from the space sur-

rounding the choke tube passes through the passage (F) to a central tube open at the top. The air and fuel mix through holes in an intermediate sleeve and pass into the main air stream through holes at the top of the diffuser. The mixture control, the purpose and use of which are referred to below, varies the flow of fuel to the diffuser, by rotating the metering valve (E).

PURPOSE AND USE OF THE MIXTURE CONTROL.

The mixture control is provided to enable the pilot to counteract the richening at altitude of the petrol-air mixture supplied by the carburettor. By correct use of the mixture control, considerable fuel economy may be effected and at higher altitudes its use is essential if trouble due to the over-rich mixture is to be avoided.

The fundamental reason for the necessity of some form of mixture control at altitude, lies in the difference between the fuel-air metering characteristics of the carburettor, and the requirements of the engine. The chemical combustion of petrol in the engine cylinder requires a definite fuel air ratio, by weight, which is practically unaffected by changes in altitude.

On the other hand, the working of the carburettor is affected by the density of both the air and petrol passing through it. While the petrol is practically unaffected by changes of altitude, the density of air is progressively reduced at higher altitudes. At 5,000 feet it has fallen to 0·862 and at 10,000 and 20,000 feet to 0·738 and 0·533, respectively, of its ground level value.

The result of this reduction in air density is that unless some form of mixture control is used, the mixture supplied by a carburettor tuned at ground level to provide the correct fuel-air ratio will become progressively richer at higher altitudes. The magnitude of this effect may best be illustrated by the figures for the percentage enrichment of the ground level mixture which occurrs at 5,000, 10,000 and 20,000 ft. These are 8 per cent., 17 per cent. and 37 per cent. respectively, corresponding with the air densities quoted above.

It is found that the power given by an engine is very nearly constant over a fairly wide range of fuel-air ratio, on the over-rich side, but falls off rapidly as the mixture is weakened. The best setting of the mixture control for economical cruising occurs when the mixture has been weakened from the setting, giving maximum power, to cause a 7 per cent. drop in power, corresponding with a fall in speed of approximately 2½ per cent. for an engine driving an airscrew of constant pitch.

In the air, the pilot can set the mixture control to give economical cruising by flying straight and level, with the boost pressure not exceeding the rated value for cruising on weak mixtures. The mixture control is then to be moved towards the " weak " position, and when the R.P.M. have fallen 2½ per cent., the desired setting will have been obtained. The engine speed should then be increased to its previous value by opening the throttle. Care should be taken to richen the mixture again when flying at a lower altitude, or with a higher boost pressure. Flying with the mixture too weak, or with high boost pressure and weak mixtures, can cause serious damage to the engine.

AUTOMATIC BOOST CONTROL.

Supercharged Engines Only.

This device protects the engine from excessive boost pressures which might otherwise occur at, or near, full throttle below the rated altitude. It also enables the pilot to fly at rated boost pressure at any altitude, below rated altitude, without reference to the boost gauge or adjustment of the throttle.

The automatic control consists essentially of an aneroid which is exposed to boost pressure, and operates a servo mechanism interposed in the control system connecting the pilot's hand throttle lever and the carburettor throttle valve. The action of the servo mechanism is such that with the pilot's control lever set at the gate, the carburettor throttle valves are moved by the mechanism to the correct position to give rated boost. As the aircraft climbs, so the throttle valves are progressively opened, until at the rated altitude they are fully opened.

Before going into a detailed description of the working of the automatic boost control unit some reference will be made to the various factors which govern its action. In the first place it should be realised that at any particular speed, the boost pressure, or induction pipe pressure is a direct measure of the power output of the engine and of the load. Certain boost pressures are arrived at during the testing and development of an engine as being the maximum boost pressures at which the engine may be run. For example, the Kestrel XVI. is rated at +6 lb./sq. in. (*i.e.*, 20·7 lb./sq. in. absolute) for take-off and +3·25 lb./sq. in. (17·95 lb./sq. in. absolute) for the normal rating. These pressures cannot be exceeded without the possibility of causing damage to the engine.

The supercharger is designed to provide rated boost pressure in the induction manifold of the engine to which it is fitted when running at International R.P.M., full throttle, at the rated altitude.

Thus for the Kestrel XVI. the supercharger maintains a boost pressure of +3·25 lb./sq. in. (17·95 lb./sq. in. absolute) in the induction pipe at full throttle and 2600 crankshaft R.P.M. when operating at 11000 ft., where the atmospheric pressure is 9·7 lb./sq. in. At lower altitudes, although the pressure ratio of the supercharger is slightly reduced by the higher air temperatures, considerably higher boost pressures would be obtained at full throttle, and at ground level the full throttle boost pressure at International R.P.M. would be of the order of +10·5 lb./sq. in. (25·2 lb./sq. in. absolute). The power output at this boost pressure would be considerably in excess of the safe maximum power of the engine, and, as referred to above, would probably damage the engine.

It follows therefore, that if the throttle control from the pilot to the carburettor were in the form of a simple link, the pilot would, below the rated altitude, have to make constant reference to the boost gauge to see that the maximum boost pressure was not exceeded. When losing height, he would have to close the throttle to maintain a safe boost pressure. Similarly, while climbing, the boost pressure would fall with every increase in height, and although not detrimental to the engine, this tendency would

necessitate continual gradual opening of the throttle to maintain the best rate of climb.

The regulator is illustrated diagrammatically in Fig. 47 and comprises an aneroid which is exposed to boost pressure (see also Fig. 46) and coupled to a piston valve for admitting boost pressure to one side or the other of a relay piston. The latter is so interconnected with the throttle control as to limit throttle opening to suit altitude, utilising the boost pressure as a relay force to perform the actual mechanical movements. The interconnection with the throttle control mechanism is effected through the

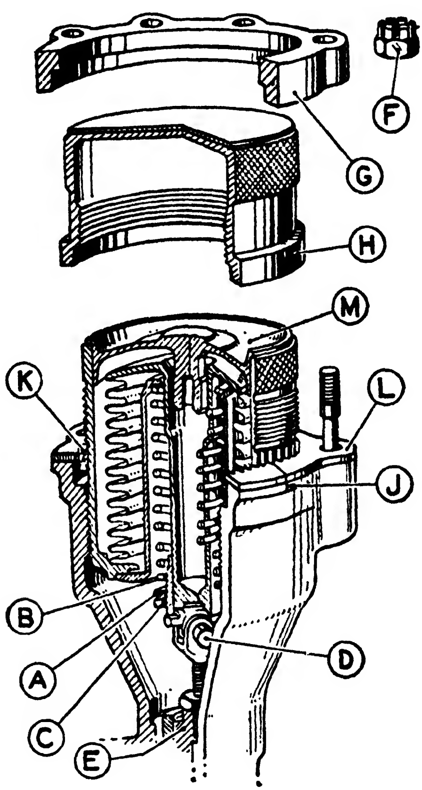


Fig. 46.—Aneroid Unit in Boost Regulator.

medium of a differential which, under normal circumstances, isolates the pilot's hand throttle lever from movement due to the relay.

At small throttle openings, when the boost pressure may be below atmosphere, and therefore insufficient to operate the mechanism with reliability, atmospheric pressure is substituted as a relay force. For this purpose a barrel-type change-over valve, coupled to the throttle control, is provided.

As a purely emergency control, a cut-out valve is arranged in the passage

which leads from the blower to the aneroid, by means of which boost pressure may be cut off from the aneroid and suction pressure substituted. The control for this valve is by means of an independent hand lever, which, normally, is sealed.

Referring to the diagram (Fig. 47), the aneroid chamber is shown at (Q) and the metal bellows at (C). Boost pressure is admitted to chamber (B), *i.e.*, inside the bellows (C), by passage (P). The spring (R) is provided to oppose collapse of the bellows and to cause the latter, when subjected to rated boost pressure, to assume a position such that ports (H) and (J) are closed. The piston valve (D) is coupled to the aneroid and controls the

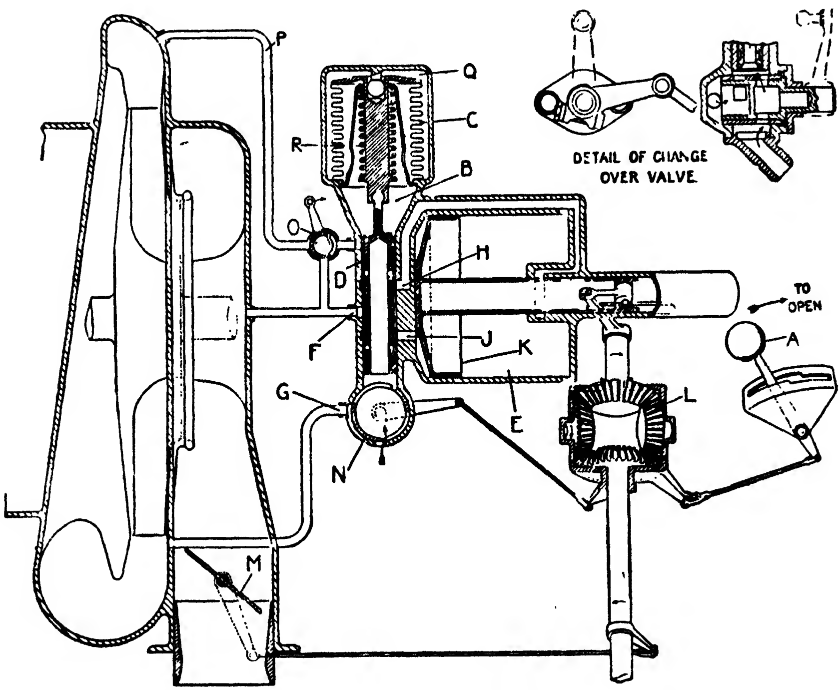


Fig. 47.—Diagram of Automatic Boost Regulator System.

admission of boost pressure by passage (G), and suction by passage (F), to opposite ends of the relay cylinder (E) through ports (H) and (J). The plunger (K) of the relay cylinder is connected to one sun wheel of the differential (L), the planet cage of which is coupled to the pilot's hand lever (A). The other sun wheel is coupled to the throttle (M). The atmospheric change-over valve is shown at (N), being coupled to the planet cage and therefore, in effect, to the hand lever (A). A cut-out valve (O) is interposed in the passage (P) and enables suction pressure to be substituted for boost pressure in chamber (B).

The way the regulator works is as follows :—The first few revolutions of the engine, with the throttle only slightly open, will produce a depression

in the aneroid chamber (B) which will cause valve (D) to be lowered and to admit the depression by passage (F) and port (J) to the left-hand end of the relay cylinder, atmospheric pressure being admitted to the other end through the valve (N) and port (H).

The throttle may then be opened by the hand control to a position which gives the rated boost, before the regulator comes into action to restrict throttle opening. This position may be as shown in the diagram. It will be seen that the change-over valve (N) is about to cause boost pressure by passage (G) to be substituted for atmospheric pressure for relay operation purposes. At the same time the pressure in chamber (B) (*i.e.*, the boost pressure) will have increased, causing valve (D) to be raised so that it is on the point of admitting boost pressure to the left of cylinder (E), and suction on the right. If the hand throttle lever be opened sufficiently to cause this to occur, the relay plunger will then be moved to the right and close the throttle through differential (L), until a state of equilibrium is reached.

If the hand throttle lever be moved to the gate at ground level, the throttle will not open further than that necessary to give the rated boost, the relay piston being then approximately at the right-hand end of the cylinder, but as the aircraft rises, this boost will be maintained by the regulator up to the rated altitude.

For purposes of take-off, or emergency, as will be later described, the hand throttle lever may be moved beyond the gate, and, acting through the differential, will cause the throttle to open further, thus over-riding the regulator and providing a boost in excess of the rated figure.

When the rated altitude has been reached, the hand lever being at the gate, the relay piston will be at the left-hand end of its cylinder and the throttle wide open. Further opening movement of the hand lever then has no effect beyond forcing the relay piston towards the right.

Operation of the cut-out valve (O) substitutes suction for boost pressure in the aneroid chamber (B), as explained. This has the effect of rendering the regulator virtually inoperative, enabling the throttle to be fully opened by the hand lever at any altitude.

It follows, therefore, that below the rated altitude, with the boost pressure below rated boost, the piston will be at the forward end of its cylinder, and movement of the pilot's control will work the throttle valve through the differential. Consider now the sequence of events at take-off. The pilot will open the throttle which, up to the rated boost pressure, will work the throttle valve directly, with the regulator piston at the forward end of its stroke. As soon as the rated boost pressure is exceeded, the piston will move to the rear of the engine, thus tending to close the throttle valve. Further movement of the pilot's lever up to the gate stop will have no effect on the setting of the carburettor throttles. However, at the gate stop the regulator piston will have almost reached the limit of its travel, and further movement of the throttle lever through the gate will bring the piston to the rear end of the cylinder. The regulator is then incapable of closing the throttles further, and any further movement of the pilot's lever will open the carburettor throttle just as it did before the regulator came into action. The boost pressure will therefore increase, and a stop on the control shaft is set to limit the pressure to the approved take-off boost.

IGNITION.

Two twelve-cylinder screened magnetos are fitted, each firing the twelve cylinders independently. The starboard magneto is connected to the sparking plugs near the inlet valves and the port magneto to those near the exhaust valves. The high tension cables are screened and fitted with ferrules for identification. The sparking plugs are screened and fitted with ball-ended terminals.

Ignition control is linked with the pilot's throttle control, so that when the throttle is closed, the ignition is fully retarded. On opening the throttle, full ignition advance occurs just before the " full open " position, as explained in the paragraphs on Controls, and at full throttle the ignition is retarded 2°.

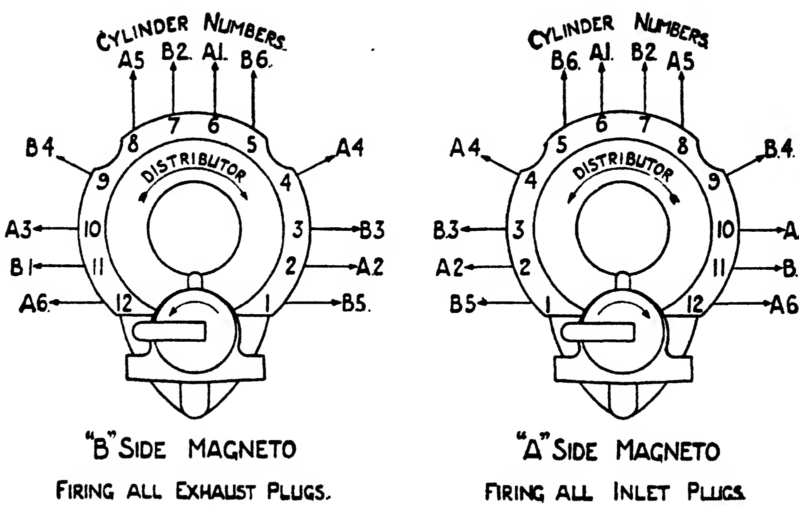


Fig. 48.—Ignition System.

DESCRIPTION OF ROTAX WATFORD TYPE S.P. 12-3 MAGNETO.

The magnetos have single contact breakers and are of the polar induction type which run at one and a half times engine speed. The port magneto rotates in a clockwise direction, looking on the driving end, and the starboard magneto is of opposite rotation.

The inductor consists of two cheeks which are assemblies of laminae mounted, concentrically, on a hollow spindle made of high tensile steel. The inductor runs in a tunnel on ball bearings. The bore of the tunnel presents six poles to the inductor, four of which are connected to the the extremities of four bar permanent magnets, and the other two form part of the armature core. The whole of the laminated pole shoes, which are made of a special high permeability steel, are cast in an aluminium

casing to ensure a solid construction, the pole pieces presenting cylindrical faces to the inductor.

The action of the inductor principle is to produce a flux change every 90° of the inductor movement, during which time the flux in the armature core has changed from its maximum intensity and passed through a zero stage and again reached a maximum value, but having a reverse polarity.

On the armature core are two separate windings, one end of each being connected to the main body of the magneto to form the earth return connection of the system. The primary is wound with a few turns of heavy-size wire on the armature core, but well insulated from the core. The secondary winding is wound over the primary winding, which has been

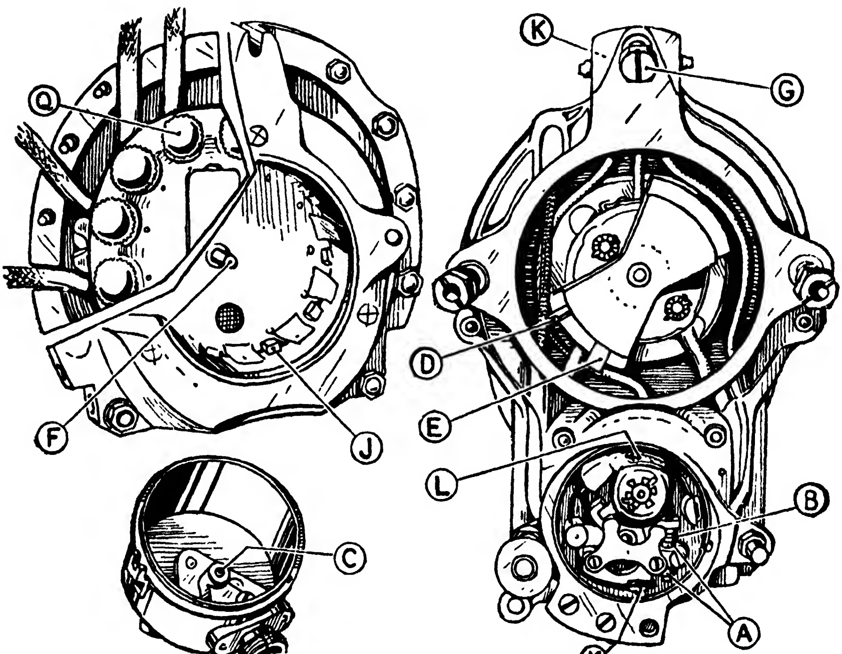


Fig. 49.—Magneto Contact Breaker with Distributor Removed.

previously insulated, and consists of a large number of turns of very fine wire.

The connection of the primary winding comes through the end bracket of the magneto in the form of a tongue with a supporting steel spring at the back (see Fig. 49). This tongue (M) makes contact with the low tension block of the contact breaker, into which is fitted the adjustable platinum tipped contact screw (A). A pivoted lever upon which is fitted an adjustable contact, has a fibre heel over which the cam passes, and opens and closes the primary circuit four times during each revolution of the inductor spindle, thereby producing four high tension sparks.

The high tension energy is conveyed from the armature winding through the centre of the high tension rotor to the rotor segments (E). The high

tension rotor runs at one-third magneto speed, *i.e.*, half engine speed, and is so timed that the high tension rotor segment (E) comes in line with the high tension segment (J) moulded in the periphery of the distributor.

The high tension cables are held in the distributors by terminal screws (Q) which pierce the cable insulation, and make contact with the core of the cable. The numbering of the connections is shown in Fig. 48.

A starting terminal is provided in the distributor to which a hand magneto is connected. A spring-loaded carbon brush (F) bears on the centre of the distributor rotor and a train of high tension sparks is supplied to segment (D) which, following the main segment, automatically retards the ignition timing for starting.

A low tension connection or terminal is provided on the contact breaker cover for earthing the magneto when the engine is to be stopped. A spring loaded plunger (C) bears on a low tension platform on the contact breaker base when the cover is fitted.

AUXILIARIES.

Supercharged Engines.

A very wide range of auxiliaries may be driven from the engine, and several alternatives are provided to allow very flexible individual arrangements to suit varying requirements.

The following auxiliaries may be driven :—

(1) Fuel Pump.
(2) Tachometer.
(3) B.T.H. High-Pressure Air Compressor.
(4) R.A.E. Low Pressure Air Compressor.
(5) Lockheed Undercarriage Pump.
(6) R.R. Gun Turret Pump.
(7) 500 watt Generator.
(8) Vacuum Pump.
(9) Operating Pump for V.P. Airscrew.
(10) Constant Speed Unit for Constant Speed Airscrew.
(11) Gas Starter Distributor.
(12) Gun Gear Cams.

The available drive positions, and alternative auxiliaries are as follows :—

I. On Starboard Side of Wheelcase.

(a) Fuel Pump.

II. On Port Side of Wheelcase.

(a) Gun Gear.

III. "A" Side Camshaft.

(a) Gas Starter Distributor.
or (b) Vacuum Pump.
or (c) Lockheed Undercarriage Pump.
or (d) B.T.H. Compressor and Tachometer Drive.

IV. "B" Side Camshaft.

(a) Tachometer Drive.
or (b) B.T.H. Compressor and Tachometer Drive.
or (c) Oil Pump and Operating Cock for De Havilland two-position V.P. Airscrew, and Tachometer drive.

V. Crankcase Lower Half.

(a) R.A.E. Compressor.
or (b) Vacuum Pump.
or (c) Dual Drive —Constant Speed Unit/Vacuum Pump.
or (d) Constant Speed Unit.

VI. Dynamo Drive at Port Side of Wheelcase.

(a) 500 watt Dynamo.
or (b) 500 watt Dynamo and R.R. Gun Turret Pump.
or (c) R.R. Gun Turret Pump.

Unsupercharged Engines.

Drives I., II., III., IV., V., are the same as for supercharged engines, with the exception that no V.P. airscrew can be fitted to the engine, and hence these units are not required.

The dynamo drive at the rear of the wheelcase is suitable for a 500 watt dynamo. No gun turret pump can be fitted.

INSTALLATION.

Unpacking.

The engine is normally despatched in a substantial wooden case, provided with four slinging eyes. The sling used for lifting should have four equal legs, not less than about 3 ft. 6 ins. long.

Four large hexagon-headed set screws will be found at the lower edges of the case, two on either side. These should be removed, when the case may be lifted off, leaving the engine bolted to a wooden cradle forming the bottom of the case.

The removal should be done carefully to avoid fouling the engine as the case is being lifted off.

It is very important in lifting the engine that the slings be arranged as shown in Fig. 50. The forward sling must pass below the rear of the reduction gear casing, avoiding the oil pipe leading to the latter. In the case of normally aspirated engines, a packing piece must be inserted between the rear sling and crankcase, and between the reduction gear supply pipe and carburettor water heating pipe, otherwise the latter will be crushed by the sling. Where the slings pass up against the cylinders, they should be sheathed with padded leather or suitably wrapped.

When the engine is likely to remain in the case for a long period, and particularly when subjected to sea air and water conditions during transport, a zinc-lined case is recommended to avoid the likelihood of corrosion of certain parts and, in order to absorb any moisture which may remain in the case after sealing, a lime box is included and fixed to the base. The packing case cover should first be removed and also the four hexagon screws at the base. The zinc lining must be cut away with a suitable tool from the metal lined case, and special sling eyes are required for removing the engine (Fig. 51).

The engine is secured to a cradle in the box by holding-down bolts through the engine feet. There is just sufficient space to enable the nuts

on the rear holding-down bolts to be detached and allow the bolts to be pushed down out of the way. The holding-down bolt holes in the engine rear feet are tapped to enable the lifting eyes to be attached with the special screws provided. A screw eye is attached to the end of the airscrew shaft

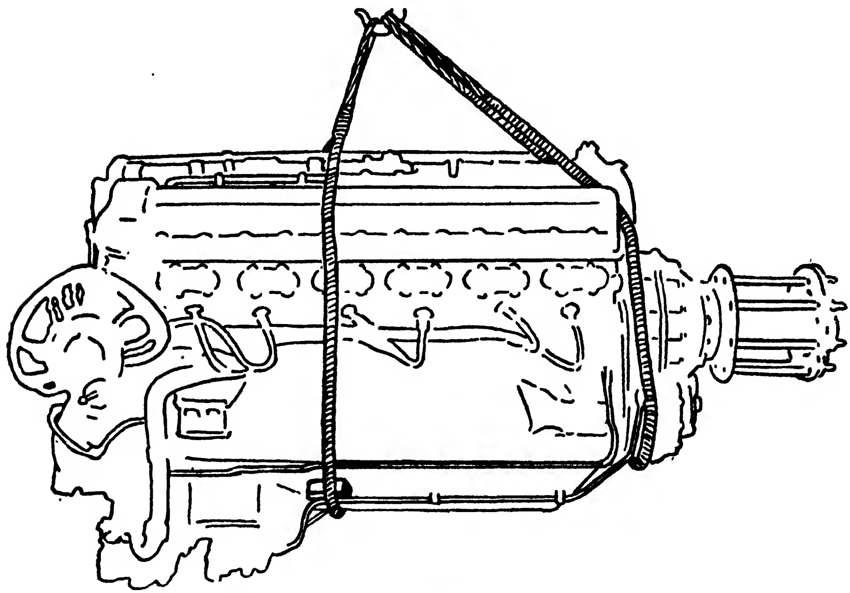


Fig. 50.—Position of Ropes when Slinging, showing Packing.

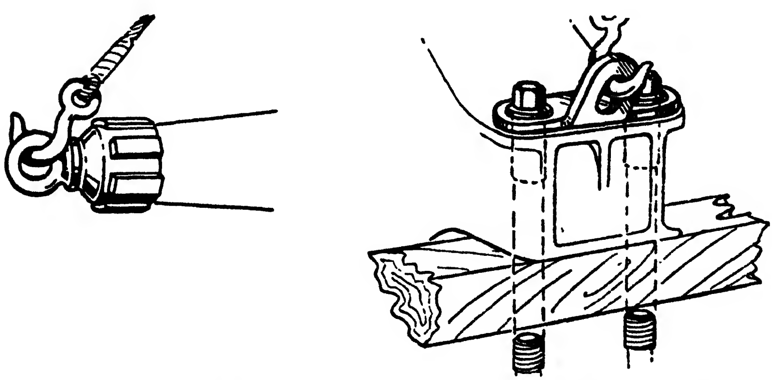


Fig. 51.—Special Sling Eyes for Removing Engine from Metal-Lined Case.

and the engine, complete with stand, can be lifted. Great care should be exercised to avoid jerking and thus throwing an undue strain on the airscrew shaft and reduction gear casing. Inspect the engine carefully for damage in transit or unpacking, particularly the pipes and projecting parts.

It should also be confirmed that the following parts are present :—

(1) Airscrew Hub.
(2) Breather.
(3) Connections for fuel pump (when ordered) and priming pipes.
(4) Copper asbestos washers for crankcase filters.
(5) Electric generator drive (less coupling).
(6) Engine Speed Indicator attachment (when not driven from B.T.H. compressor).
(7) Exhaust flanges and nuts.
(8) Fuel drain pipes.
(9) Hand starting mechanism less handle.
(10) Magnetos.
(11) Nuts and nipples for oil and fuel pipes.
(12) Packing for engine feet (2 Ferodo and 4 rubber packings, together with 2 aluminium plates).
(13) Priming pipes.
(14) Rubber connections for water inlet and outlet pipes.
(15) Water drain.

Supercharged engines only:
(16) Air Intake Gauze.
(17) Automatic Boost Control.
(19) Air Intake.

When Ordered:
(20) Filter for oil feed.
(21) Electric generator couplings.
(22) Fuel Pump complete with driving gear.
(23) Gas Starter Distributor with pipes and valves.
(24) Gun gear—engine fittings.
(25) Hucks starter claw with integral spider.
(26) Starting handles.

Engine Mounting.

Provision has to be made in the engine mounting for the expansion which occurs when the engine warms up to its operating temperature, amounting to approximately 0·065 in. Suitable clearances holes are provided in the rear engine feet, and the bolt holes in the engine mounting should be drilled to the dimensions given on the makers' installation drawing, or to the detailed sketch in Fig. 52. The engine mounting itself is likely to expand to some extent, but lack of proper provision for engine expansion may lead to serious stresses being set up in both the engine and mounting.

The engine feet are flat, as illustrated, and packings are supplied with the engine for insertion between the feet and engine bearer, Ferodo being used for the front feet, and rubber both under, and above, the rear feet. If tubular engine bearers are used they must be fitted with saddle pieces to correspond with the engine feet, and the holding down bolts will then pass through the tubes.

Before lowering the engines into position the engine feet and platforms must be carefully cleaned, and great care should be exercised in lowering the engine on to the holding-down bolts to avoid fouling the side water pipes at the rear of the engine, owing to the small clearances at this point.

The bolts through the front feet should be screwed up tightly, but owing

to the presence of the rubber packings the bolts through the rear feet should only be tightened until the rubber is slightly compressed.

In a mounting of the cradle type used in many Kestrel installations, the side structures are connected underneath the engine by a system of cross-struts and vee-bracing, and the airscrew torque is divided approximately equally between the front and rear feet.

Fuel System.

The carburettor float feed mechanisms are adjusted to operate between pressures of 2 ft. and 12 ft. head of fuel from either gravity or fuel pump feed.

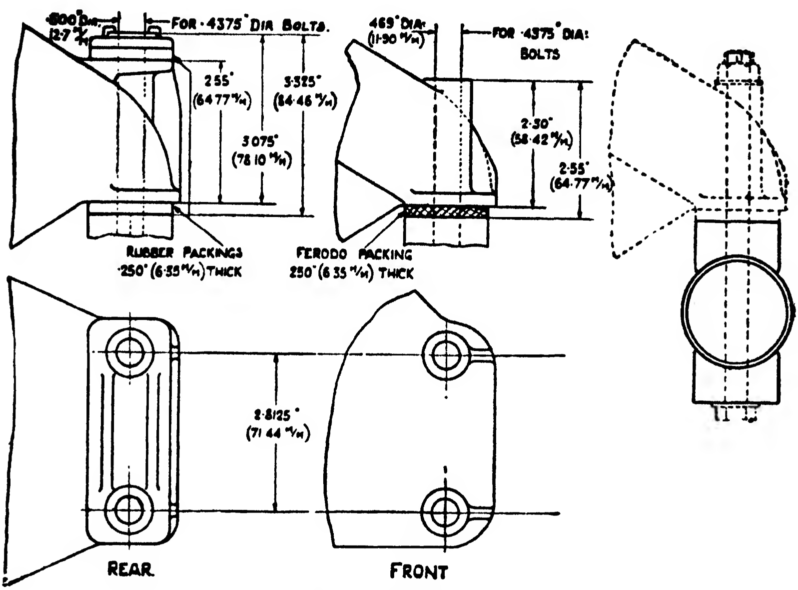


Fig 52.—Engine Feet.

Suitable connections for fitting ⅜ in. bore Petroflex piping are provided on the fuel pump and carburettor supply, and the air intakes are fitted with connections for $\frac{5}{16}$ths drain pipes.

In the case of normally aspirated engines, two Petroflex drain pipes are fitted, from the front and rear carburettors, and are brought to connections on the left-hand side of the crankcase.

As the fuel pump has a capacity greater than the maximum consumption of the engine, it is fitted with a suitable relief valve. A priming connection is supplied for use when the fuel tanks are below the level of the pump. When an additional gravity tank is fitted, a non-return valve is necessary to prevent the possibility of the pump feeding back into the gravity tank when the cock is open. The venting of the tanks is important.

Two typical fuel systems are shown in Figs. 53 and 54, but it should be emphasized that the lay-out is governed largely by the location of the

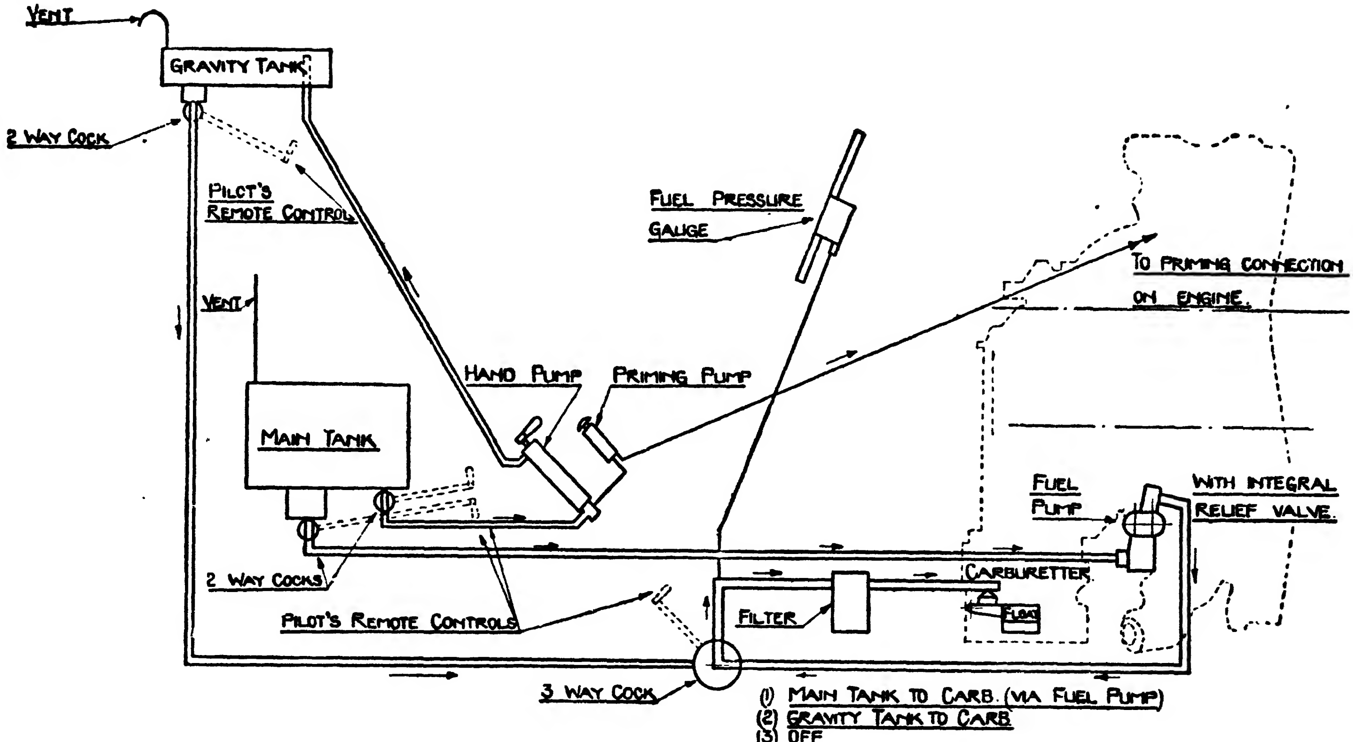


Fig. 53.—Diagrammatic Sketch of Fuel System having One Main and One Gravity Tank.

tanks and other requirements of the aircraft, and no general recommendations can be made.

The fuel system in Fig. 53 incorporates a gravity tank, which can be re-filled in flight by means of a hand pump. In the event of failure of the fuel pump the machine can be flown on the gravity tank only, and the latter re-filled from the main tank as required. This system is suitable for a biplane with gravity tank in the upper wing.

Fig. 54 shows a system for a low wing monoplane having one fuel tank in either wing, and no gravity tank. Hand and primer pumps are provided for emergency use and priming respectively.

As no filters are incorporated in the carburettors (except for the slow-running device), arrangements should be made for their inclusion in the pipe line.

The connection from the priming pump distributes the fuel to four nozzles in the induction manifolds, the piping forming a unit with the volute drain distributing pipes on supercharged engines.

It is desirable to include a pressure gauge in the pipe line between fuel pump and carburettors or service tank, according to the system used.

A flow test should be made by disconnecting the float chamber feed to ascertain that the pipe system will pass at least 80 gallons per hour. This flow test allows the pipe system to be flushed out.

Oil System.

In a normal system, the engine pressure pump draws oil from the tank through a separate filter mounted on the air frame. This should be accessible for cleaning. After circulating through the engine, oil is drawn through the two scavenge filters by the scavenge pumps and returned to the tank, after passing through the oil cooler. Such a system is shown in Fig. 55.

It is essential that the system be free from air leaks, particularly at the crankcase filter joints, in order to prevent the accumulation of oil in the sump when gliding or diving, which will be indicated by the exhaust showing oily smoke.

Piping of 1 in. outside diameter should be used for the suction line, and $\frac{5}{8}$ in. outside diameter for the scavenge or return line. A pressure gauge connection is fitted on the H.P. supply pipe, and also a suitable thermometer connection at a similar point.

The warming-up period can be reduced by using the Rolls-Royce divided oil tank arrangement which allows only part of the oil to circulate when cold, as shown in Fig. 55. The circulating compartment has a minimum oil capacity of 1·5 gallons while the bulk of the oil is in the reserve compartment, connected by holes in the partition. When starting from cold the engine is ready for take-off when the circulating oil has reached a temperature of 15°C., and the warming-up period will be much shorter than that required for all the oil to reach this temperature. When the oil is hot there will be a gradual mixing of the oil in the two compartments, through the holes in the partition.

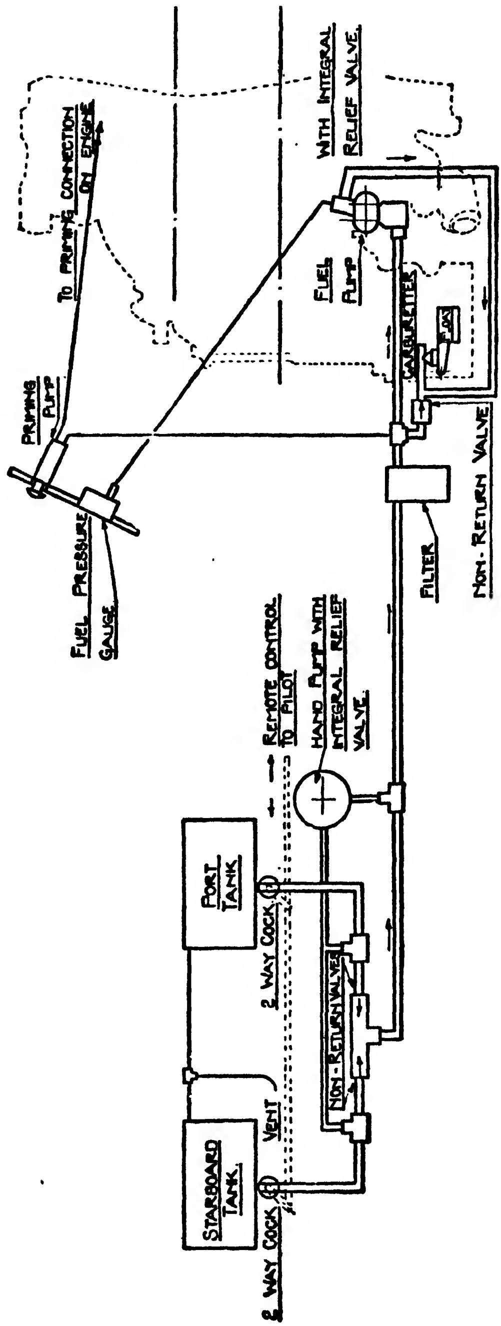


Fig. 54.—Diagrammatic Sketch of Fuel System having two Wing Tanks.

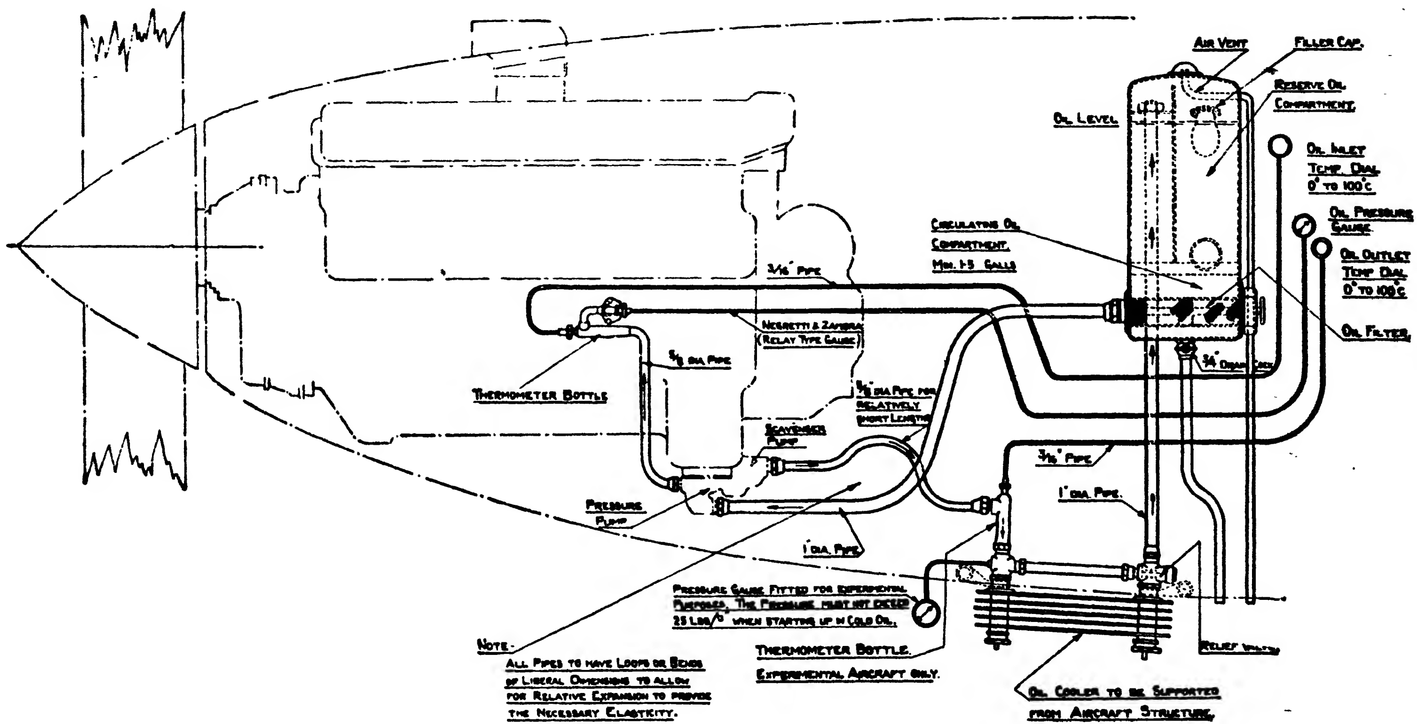


Fig. 55.—Diagrammatic Arrangement of Oil System.

The filter used should be easily cleaned and must not trap a column of air when the cover is replaced. For this reason, the detachable cap should be at the top, and the gauze cylinder arranged to trap the impurities

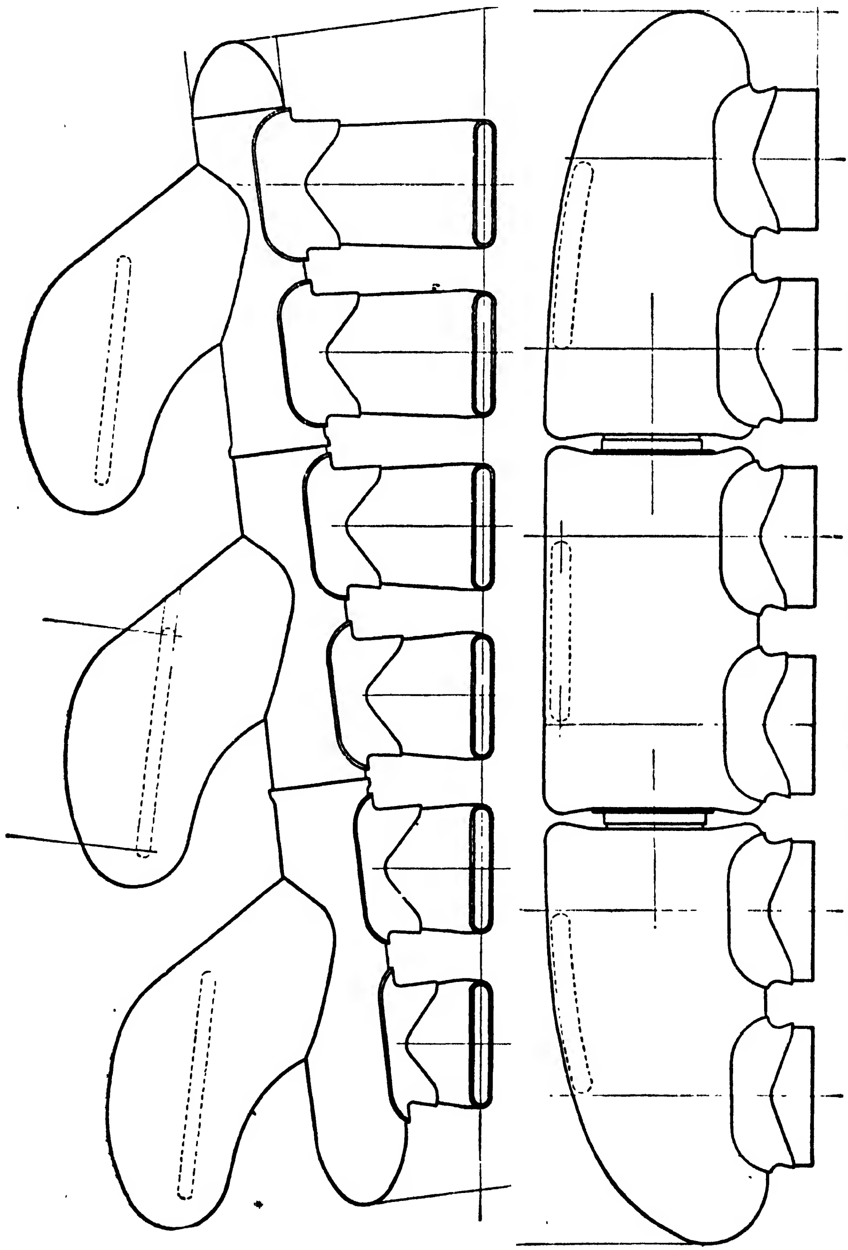


Fig. 56.—Exhaust Manifold Types. Ram's Horn and Streamline.

on the inside. The gauze can then be lifted out and cleaned and, before fitting the cap, the filter body can be filled with oil by turning on the main cock controlling the supply from the tank. Where such a cock is fitted, it should be interconnected with the fuel cock or ignition switch to ensure that the engine cannot be run without first turning on the oil supply. A filter incorporated in the oil tank and having no cock in the main feed to the engine is preferable, from this point of view.

The oil cooler should be of such a capacity that the temperature of the oil supplied to the engine does not exceed 80°C. A lower normal temperature is preferable. A maximum inlet oil temperature of 90°C. is allowable under special circumstances, but only if the main oil pressure does not fall below 40 lbs./sq. in.

Exhaust System.

The general requirements of an exhaust system are:—(1) Low drag and weight. (2) Efficient flame damping. (3) Good silencing properties. (4) No interference with pilot's view. (5) Good service life.

Flame damping and the suppression of noise are allied with the degree of cooling and gas expansion, but in order to meet the weight and drag conditions the size and surface must be reduced to a low figure. Based on these requirements the long tail pipe was superseded by a "Ram's horn" (Fig. 56 top) manifold in which six cylinders of one bank exhaust into a common pipe, the discharge taking place through narrow slots in 3 lobes which project into the slipstream, and from which the manifold derives its name.

A streamline "blister" manifold is also shown (Fig. 56 bottom), being an improvement as regards weight and drag over the "Ram's horn" type. The discharge of the exhaust gas through a narrow slot assists both in the silencing and flame damping properties of the manifold. An alloy of nickel, chromium, and iron has been found to be the most satisfactory material.

Cooling System.

The design of cooling systems for a liquid-cooled engine requires special care to ensure reliable operation. The principal trouble which is liable to occur in flight with a badly designed system is loss of water from the vent, due to the formation of air or vapour locks in the system, which must also be suitable for aerobatics or inverted flight. When boiling occurs, only steam and no water should be lost from the vent.

Although, for convenience, generally referred to as "water," the recommended coolant for Kestrel engines is a solution of 70 per cent. water and 30 per cent. ethylene glycol. This solution, with a freezing point of −15°C. and a boiling point of 102·5°C. at sea level, was originally used to prevent freezing during the winter months. It is, however, equally suitable for summer use, and in view of the fact that the change from water to glycol solution is liable to loosen any deposits which may have formed in the cooling system, leading to a partially blocked radiator, ethylene glycol solution is now standardised for use all the year round.

A typical water system of the simplest type is shown in Fig. 57 and this will be described before proceeding to a detailed analysis of the various troubles which can be eliminated by correct design.

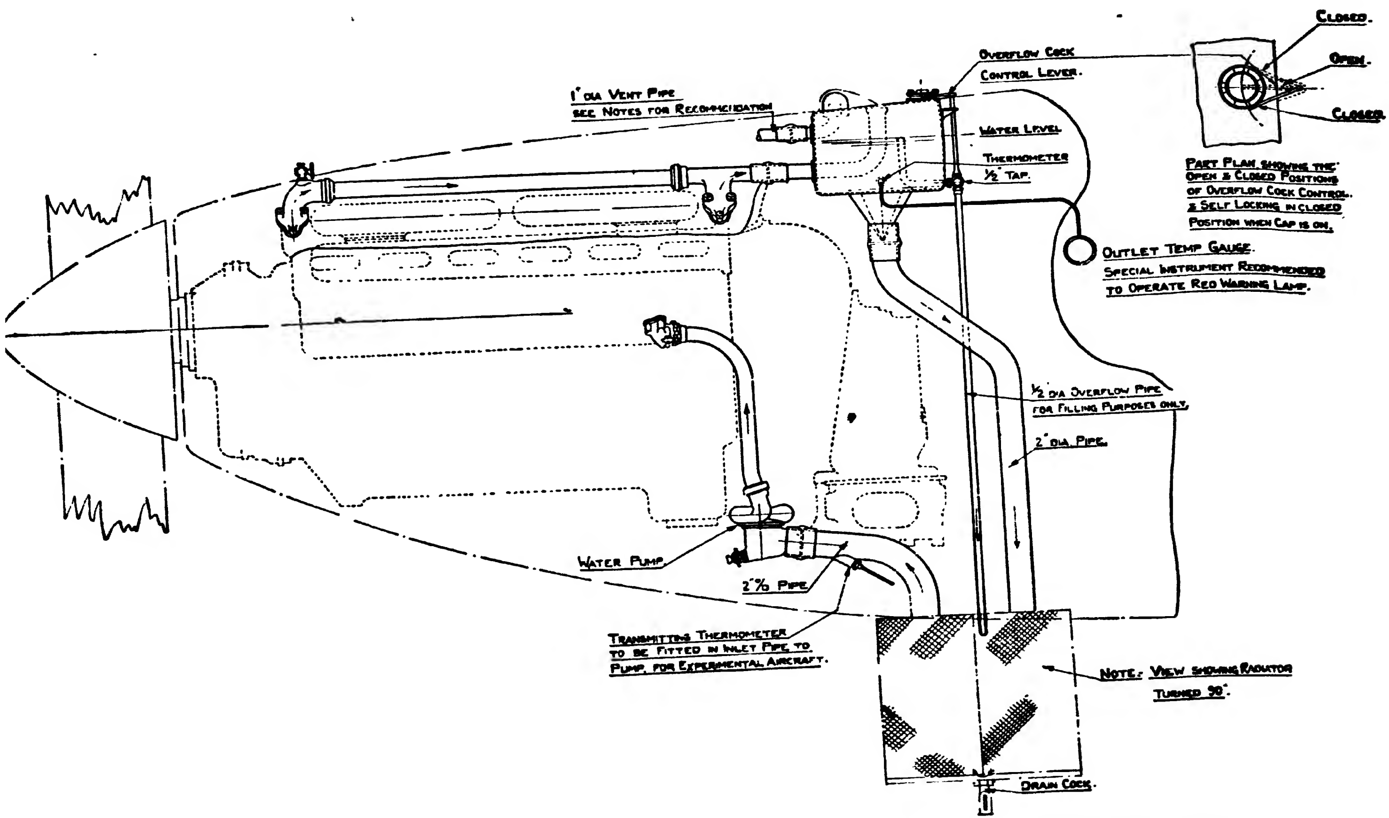


Fig. 57.—Diagrammatic Arrangement of Water System, Single Engined Aircraft—Supercharged Engine.

The centrifugal pump below the crankcase draws water through the radiator from the header tank. The water is then discharged by the pump through each cylinder block and returns to the header tank. The circulation at normal engine speed is approximately 105 gallons/min., and the water capacity of the engine is about 4·5 gallons. On supercharged engines each cylinder block has a top water rail into which the coolant is discharged, and these pipes have forward or rearward outlets according to the position of the header tank. Unsupercharged engines have a single central discharge pipe with a rear outlet. Restriction washers are fitted at the cylinder inlets and at the rear outlets to reduce the tendency for the circulation to reverse at high temperatures, when throttling back.

On supercharged engines the main connections are arranged for a 2 in. diameter inlet and two $1\frac{3}{4}$ in. diameter outlet pipes. These sizes should also be used throughout the system, except when both outlets are connected, the single return pipe then being increased.

The main inlet and outlet connections on normally aspirated engines are arranged for 2 in. diameter pipes, which size should also be used throughout the system. A thermometer fitting is also provided at the pump inlet and main outlet pipes.

The air release cock is fitted at the front end of each main water outlet pipe and a suitable drain cock is provided at the base of the carburettor or water pump. An accessible drain should be arranged at the lowest point in the system.

When a pressure system is used, the relief valve should allow a pressure of approximately $+2\frac{1}{2}$ lbs./sq. in., but must also allow admission of air when a depression to the extent of $-\frac{1}{2}$ lb./sq. in. obtains under cooling conditions. For normal flight, the specified temperatures of 75-85°C. should not usually be exceeded.

Header Tank.—Besides providing a reserve supply of water, it is the duty of the header tank to separate the steam and water issuing from the cylinders when near the boiling point. It is in the design of this component that most attention has to be given, for avoidance of water loss. When the radiator is placed below the engine, as shown in the sketch, the header tank should be above the engine, either at the nose above the reduction gear housing, or at the rear as shown.

Ample air space should be provided, to provide for the rise of water level above cold filling level, when nearly boiling. The expansion of the water when hot is largely counteracted by the expansion of the pipes and other parts of the system.

The outlet pipe from the cylinders to the header tank should discharge above the surface of the water at the highest point in the tank, to cause a minimum disturbance, and should preferably discharge vertically on to the curved surface of the top of the tank, as shown in Fig. 57. By this arrangement the water streams down the sides of the tank in a thin layer, and vapour separation is assisted.

The water outlet from the header tank to the radiator should be arranged to prevent the formation of a vortex which is liable to admit a core of air into the water stream entering the radiator. This would have the double disadvantage of raising the water level in the header tank by displacement, which might cause water loss, and also of reducing the suction ability of the pump. It may also cause air locks and stop circulation.

Such a vortex can be prevented by making the outlet pipe rectangular where it leaves the tank, or, as shown, by making it conical with radial triangular baffles.

The locomotive steam dome type of vent has been found to give the best results. This should be situated on the centre line of the tank, and at the forward end, to be at the highest point in climbing altitude. The vent pipe should be at least 1 in. diameter and, if it is led down to the bottom of the radiator, will minimise water loss when flying inverted. There should be metallic contact between the radiator and vent pipe, to prevent freezing of the latter.

Baffles inside the tank are an advantage in helping to suppress turbulence in the water when boiling, and also when taxying over bumpy ground. These baffles should be perforated with large holes and should not be above the normal water level in flight. They should extend down to within about ¼ in. of the bottom of the tank.

Some indication of the correct level should be provided for filling, such as by the provision of a side filler orifice, set at the desired level, making it impossible to overfill the system. Another method, shown in Fig. 57, is to have an overflow pipe at the correct level, controlled by a cock, the operating lever of which is incorporated in the locking device for the filler cap. This ensures that the overflow cock is open when the filler cap is off, and closed when the cap is locked in position. The overflow pipe should be led outside the cowling so that the ethylene glycol solution may be collected.

The radiator should be placed in the slipstream, to provide adequate cooling when running up on the ground. It is of the utmost importance to avoid undue resistance to flow through the radiator, since this restriction may seriously impair the circulation when operating near the boiling point, the suction of the pump then being considerably reduced. The depression at the pump inlet is controlled by the restriction caused by the radiator, and if the pressure falls to the vapour pressure of the coolant, vapour locks will be formed, resulting in water loss and the possibility of a complete cessation of flow. Since the vapour pressure increases rapidly with increasing temperature, every effort should be made to keep the pressure at the pump inlet as high as possible. This can only be done by having the header tank as high as it can conveniently be placed, and making the pipes short and of ample diameter, without sharp bends. The water pump is at the lowest point for this same reason.

The effect of increasing altitude on the coolant flow is also of considerable importance, since the pressure at the pump is further lowered. Whereas on the ground the flow will fall off above 70 to 80°C., and may become only 50 per cent. of the normal at 100°C., the effect of increasing altitude is to lower these temperatures in conformity with the fall in boiling point.

To prevent air locks due to air which may enter the system when inverted, the suction pipe from the radiator to the pump should, if possible, be made to slope upwards all the way, with no curves which might trap air.

Tests which should be made on a prototype cooling system include:—(1) Water loss test when boiling. (2) Circulation at ticking over speeds. (3) Depression tests at the pump inlet, at 80 to 85°C. (4) Radiator suitability tests, under climbing conditions at various altitudes.

Composite Cooling System.

In this case, the cooling system comprises a combination of water and steam cooling. A higher cooling temperature may thereby be used, 105°C. outlet measured at header tank and pressure 0 to 1 lbs./sq. in., allowing the size of radiator, and corresponding air resistance, to be reduced, and at the same time avoiding loss of water by steaming. This temperature covers both glycol mixture with water, and water only. A typical installation is shown in Fig. 58.

The working of this system is as follows :—The water pump (A) circulates water through a radiator (B) and each cylinder block, returning it to a header tank (D) in the normal manner. In addition, a condenser

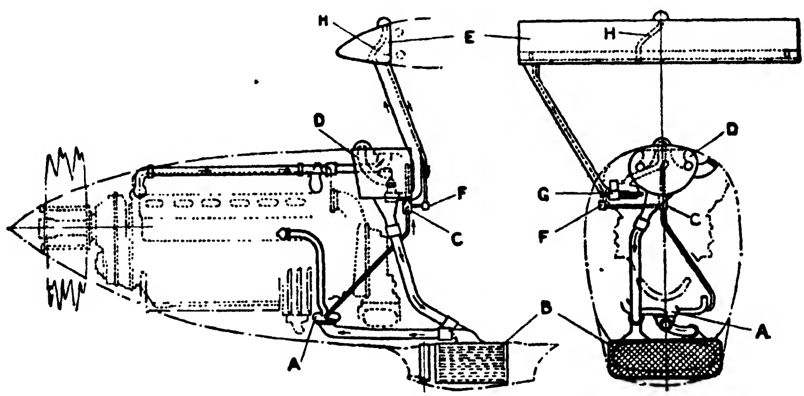


Fig. 58.—Composite Cooling System.

(E) is provided for condensing steam formed in the system. The condensate from this condenser is returned to the system by an ejector (C) energised by the water pump. When steaming occurs, therefore, water is not lost in the form of steam. The header tank is not vented to atmosphere as in the normal water cooling system, and to avoid excessive header tank pressure the pipe connection in the condenser should not be less than 1 in. outside diameter. Owing to a slight pressure in the header tank when steaming, the condensate will not successfully return by gravity as would appear likely. The valves (F) and (G) are provided for inverted flying conditions, preventing the water in the system draining back to the condenser, and also allowing pressure to be released if generated under such conditions. The condenser is vented through passage (H) to the base.

Care and Maintenance of the Cooling System.

As referred to on p. 339 the recommended coolant for Kestrel engines is a solution of 30 per cent. ethylene glycol in water. There is no risk of corrosion or injury of any kind to the system by its use, and it has been found, in fact, that such a solution is less corrosive than pure water. It is essential, however, that before using it, the condition of all rubber connections should be carefully inspected, as ethylene glycol has a tendency to attack rubber, especially if this is already in a somewhat perished condition. It is best to inspect the insides of one or more rubber connections and replace them all if there be any sign of flakes of rubber becoming detached.

When filling the system, care should be taken to avoid air locks. All the water should pass through a filter. In the Rolls-Royce system of open circuits there is little danger of faulty filling, but owing to the differing types of installation the following points should be observed :—

(1) If the radiator is of the " retractable " type, this should be wound to its " full out " position prior to filling, and the bottom drain tap should be left open until a steady flow of water issues from the orifice. The tap should be closed while the water is running, and care should be taken that the vents in the top water rails are open. These are arranged at the front ends of the water pipes.

(2) Having filled the system to the correct level, the vent taps should be turned off, and the engine run for five to ten minutes. The water level should then be examined again. It will probably be found that circulation of the water has removed small air pockets from the system and that a further gallon or so can be added to correct the level.

(3) Where the capacity of the water system is known, the amount should be checked as poured in. This will give an indication of the occurrence of air locks in the system, as the correct filling level will be reached before the full quantity has been poured in.

(4) Gentle rocking of a smaller type machine will sometimes displace an airlock.

(5) Care must be taken that all water pipe joints, clips, etc., are sound and that the radiator or header tank is correctly filled.

To prevent furring of the radiator and pipe lines caused by the precipitation of mineral salts from hard water, the water used must (unless distilled or rain-water is available) be tested for hardness, and softened where necessary. The softening can be accomplished by the addition of appropriate quantities of sodium phosphate.

Where there is any doubt that the water circulation is working satisfactorily, as may be shown by sudden fluctuations of the thermometer needle, or sudden rushes of water from the header tank or radiator vent pipe, a check can be made by temporarily connecting a vacuum gauge to the main cock at the water pump inlet. Any cessation of flow will then be indicated by the depression at the pump inlet falling to zero, which may be consistent with the fluctuations of the thermometer needle and loss of water. Investigation into the cause of the trouble may reveal partially furred pipe lines, radiator, or water system generally.

If suspected of being furred the radiator should be removed for a flow test. It should be found that approximately 75 gallons a minute will

flow through, under a head of 7 feet. If the flow is less and furring is evident, the radiator and the rest of the water system should be washed out with some suitable solution, such as phosphoric acid and an inhibitor such as Rodine. Another possible cause of reduced flow is a deposit of grease on the radiator tubes, caused by over-lubrication of the water-pump gland. The grease can be removed by the correct use of caustic soda or tartaric acid solution.

The water pump gland is an item which requires correct maintenance to ensure reliable operation. When fitting a new packing, the gland nut must not be overtightened as it will damage the packing and necessitate starting again. The best results are obtained from a new packing if the gland nut is left quite slack and the engine run with water leaking through the gland. The gland nut should then be tightened up by hand, when the leak will cease and a good gland surface should be obtained. It must first be confirmed, however, that the rotor spindle is not badly worn; as otherwise the fitting of a new gland packing will be useless.

Excessive lubrication of the gland, as a temporary cure for leakage is liable to result in damage to the cylinder top joints besides forming a restriction in the radiator. The grease gets into the water system and collects at the tops of the cylinder liners where its presence prevents efficient cooling and results in local overheating and distortion. It is sufficient to give the lubricator one turn after approximately every 10 hours flying.

It is important that any water leaks observed on the ground should have immediate attention, as what appears to be a small leak on the ground may cause a serious loss of water in flight. The system should be " topped-up " prior to flight.

Due to the low freezing point of the ethylene glycol solution (—15°C.), the cooling system need not be drained under normal winter conditions in England. Where, however, there is a possibility of the aircraft being stored under lower temperature conditions, the ethylene glycol solution should be drained from the system and preferably kept for future use to avoid waste. The drain plug should be at the lowest point in the system and should not be replaced until it is desired to refill the system, as although it may be believed that the system has been drained, a certain amount of water continues to trickle through, probably due to condensation. During the process of draining, it is an advantage if the tail of the machine can be lifted up and down, to drain any pockets which may exist either in the " down " or the " up " positions.

SETTING THE THROTTLE GATE.

When the connection is being made from the pilot's throttle lever to the throttle control lever on the engine, it must first be ascertained that the range of movement is adequate. With the pilot's throttle lever right back, the carburettor throttle must be at the slow-running stop, and with the pilot's throttle fully forward, or opened—through the gate, the engine control lever for a supercharged engine must be at the stop which regulates the take-off boost setting.

The boost regulator is set and sealed at the rated boost position, and the throttle gate can be set with the engine stationary. After running the engine at low speed to ensure that the relay piston is right in (*i.e.* forward), the pilot's lever should be advanced until the main butterfly throttles are on the full throttle stop. The position of the piston should then be checked, to ensure that it is still right in, and the gate can then be fixed on the quadrant in this position. This setting ensures that full throttle is obtained at the rated altitude, and that at no time is any movement of the regulator transmitted to the pilot's lever. The effect of too low a setting of the gate is that full throttle is not obtained at any height. With the gate set too far forward, the rated altitude and full throttle will be reached before the regulator piston is at the forward end of its stroke. Any increase in height will then cause the piston to move forward and tend to move the pilot's lever back to its correct setting.

Take-off Boost Setting.

This can only be set with the engine running. The pilot's lever should be moved through the gate until the correct take-off boost pressure for the particular engine type is reached. The stop on the transverse control shaft on the engine should be set to this position.

Movement of the throttle through the gate, while the engine is on the ground, over-rides the boost control as the piston will then be fully out, and at the limit of its travel in the direction which closes the throttle. The pilot's lever will, therefore, be directly linked to the throttle valve. It follows that the setting of the take-off stop gives a definite setting of the throttle valve.

It should be noted that the "static" setting so obtained will not be correct when the machine is air-borne, due to the increase in speed, etc. Allowance should be made for this in the static setting, and the correct setting, which may vary with different installation, can only be found by experience. As an example, for Kestrel V., having a take-off boost of +6 lb./sq. in., the stop is set to give approximately +5½ lbs. on the ground. When the aircraft has attained flying speed, the boost pressure then rises to its correct value of +6 lb./sq. in.

Variations in atmospheric pressure will alter the take-off boost pressure, and it must be assured by reference to the boost gauge that the maximum take-off pressure is not exceeded.

Special and Tropical Aerodrome Conditions.

If the height of the aerodrome is more than, say, 1000 ft. above sea level, then the absolute boost pressure for take-off with the throttle lever

moved through the gate to the stop will be lower than the rated take-off boost, due to the reduced atmospheric pressure.

The result of this lower pressure is a reduction in power for take-off, and if the atmospheric temperature is also high (35°C. and over), the take-off power will be reduced very considerably.

The " all-up " weight of the aircraft in which the engine is installed, must therefore be reduced to maintain the same performance at take-off, in regard to take-off run, and the distance from rest to clear a given height.

Method of Altering Rated Boost.

Should any change in the engine rating be authorised, necessitating an alteration to the boost control setting, the following procedure must be adopted. Only small variations in boost pressure may be made by this means.

Before making any alterations, it should be confirmed that the controls, relay piston, and aneroid unit valve are all free and in working order.

The washer (A) (see fig. 46) is suitably adjusted by the makers, and the unit tested for a given rated boost, determined by the engine Series. With this object the top face of the aneroid chamber (M) is marked accordingly, and the unit must not be used in an engine of a different series, and correction then made by the above adjustment.

Break the seal attached to the boost regulator studs and remove nuts (F), the cover (H), and serrated locking washer (L) after first marking the relative positions of the serrated ring and casting, and the aneroid chamber and serrated ring, as shown at (J). The aneroid unit can then be screwed up or down; a downward movement (clockwise) increasing the rated boost, and an upward movement (anti-clockwise) decreasing the rated boost.

With the engine stationary, screw the aneroid unit a few serrations (K) at a time, then replacing and securing cover (H) and locking ring (G). Approximately twelve to fifteen serrations will make 0·5 lb./sq. in. difference in boost pressure.

Run the engine up and observe the boost gauge (or mercury U tube) reading. When rated boost has been obtained, the relay piston must float; that is, the pilot's lever can be moved up to, and back from, the gate a certain distance without any alteration in boost occurring.

Should complete removal of the aneroid unit be necessary, the number of complete turns required for removal should be noted. This will enable the original setting to be restored and thus avoid unnecessary ground running of the engine.

When setting boost pressures either for take-off or re-rating, these pressures should be based on the international standard atmosphere at sea level, that is, at a temperature of 15°C., and a barometric pressure of 760 mm. (29 92 ins.) of mercury (14·7 lb./sq. in. absolute). When using a mercury U tube, the pressure recorded will be referred to the prevailing atmospheric pressure, and this pressure must be known, to make the necessary conversion to absolute pressures.

As an example, consider the reading of the U tube corresponding to a boost pressure of +3·25 lb./sq. in. on a day when the barometer stands at 30·14 in. of mercury. The absolute boost pressure will be 29·92+(3·25×2·04) =36 55 in. of mercury since 2 04 in. of mercury are equivalent to

1 lb./sq. in. The U tube reading will therefore be (36·55 − 30·14) = 6·41 in. of mercury, and this would be the reading of the U tube to which the boost should be set to give +3·25 lb./sq. in.

The boost gauge on the aircraft should always read the absolute pressure above or below 14·7 lb./sq. in., which corresponds with zero on the scale. When the engine is stationary the boost gauge should register the atmospheric pressure. For example, a reading of − 0·5 lb./sq. in. should correspond with a barometric pressure of (29·92 − 1·02) = 28·90 in. of mercury and a reading of +0·5 lb./sq. in., with a barometric pressure of (29·92 + 1·02) = 30·94 in. of mercury. The boost pressure can, therefore, be set by the boost gauge reading without reference to the barometer, but on account of its greater accuracy a mercury U-tube and barometer reading should be used.

PROCEDURE AFTER INSTALLATION OR A LONG STAND-BY.

When it is desired to start a new engine or one which has been specially prepared for a long stand-by, any mineral oil which may have been placed in the cylinders to prevent corrosion must first be removed. Where corrosion inhibitor E.G. 174 has been used, in place of mineral oil, after running on leaded fuel, this precaution is unnecessary as usually only 10 cc. and not more than 50 cc. of the liquid is sprayed into the cylinder and this need not be removed.

The installation should then be checked over to see that all bolts, nuts and pipe lines are in order, and correctly locked where necessary, and the airscrew and hub examined. The working of all controls and such connections to the engine as pressure gauge, oil thermometer, ignition switch, and starter magneto lead should also be checked.

The cooling system can now be filled with 30 per cent. ethylene glycol solution, as detailed on page 344.

After checking the quantity of petrol in the fuel tank and the gravity tank if fitted, the oil system can be filled, preferably with hot oil, especially in winter.

If the engine is not new, but has been standing in the machine for some time, it may be advisable to clean the oil filters and drain the oil system, which should be refilled with fresh oil.

Where an oil cock is fitted in the pipe line from the tank to the engine, this should be locked in the "on" position.

The engine is then ready for starting.

INSTRUCTIONS FOR STARTING THE ENGINE.

When starting an engine, the cylinders must be filled with a combustible mixture of air and petrol vapour. Too little, or too much petrol vapour in the mixture will make it incombustible and the engine will fail to start. For this reason, different procedures are required depending on the temperature of the engine.

In normal running the fuel-air mixture has to pass from the carburettor through the supercharger and induction pipe before reaching the cylinders. When the engine is cold the petrol vapour condenses on the cold metal walls during the passage of the mixture. For this reason a priming system is fitted, whereby liquid petrol may be sprayed direct into the induction pipe. Too much petrol must not be injected, otherwise the mixture may be over-rich.

When an engine is hot, there is no such condensation and the mixture is more likely to be too rich than too lean.

Cold Starting.

The following instructions apply to the starting of an engine when it is cold :—

Hand Starting.—Turn on the fuel and oil, close the throttle, and switch off the magnetos. Pull the engaging rod or cable to bring the worm into mesh with the worm wheel and at the same time engage and rotate the starting handle. Continue rotation of the starting handle until a decided increase in load is felt ; this corresponds with full meshing of the worm and worm wheel. At this point, the engaging rod or cable should be released, as this must never be held while the engine is being turned, otherwise, in the event of the engine starting, the worm would not be free to unmesh and damage would occur. Turn the engine slowly, and, at the same time, inject four or five pumpfuls of fuel by means of the priming pump. When the engine is hot, little or no priming should be given. Continue to turn, open the throttle slightly, operate the hand-starting magneto and switch on all magnetos ; the engine should then start. As soon as the engine starts, switch off the hand-starting magneto and turn off the primer fuel supply.

Use of Hucks Starter.—Turn on the fuel and oil, switch off the magnetos and open the throttle slightly. Engage the starter claw and turn the engine, at the same time giving four or five pumpfuls of fuel by means of the priming pump, if the engine is cold. Little or no priming should be given if the engine is hot. Operate the hand-starting magneto, switch on all magnetos, and the engine should start. After starting, cease operating and switch off the hand-starting magneto. Turn off primer.

Gas Starting.—See that the air cylinder holds a pressure of between 80 and 200 lbs./sq. in., turn on the fuel and oil and prime the atomiser. Set the throttle slightly open, turn on the master cock, and switch on the hand-starting magneto. Operate the hand-starter magneto and depress the press cock. As soon as the engine fires, switch in the main magnetos and release the press cock ; the engine should continue running on its own induction and ignition systems. Turn off the master cock, and switch off the hand-starting magneto.

Priming.—In the above starting operations the number of pumpfuls of fuel specified is the amount of fuel that should be discharged into the induction manifolds. Actually, it will probably take several additional strokes of the primer to fill the priming system pipes before any delivery into the induction system is effected. The extra pump strokes for this purpose will vary with different aeroplanes, and personnel should endeavour to learn the priming requirements of the type of aeroplane with which they are dealing, and to judge when the priming system is full of fuel by the resistance felt when operating the plunger. Do not forget to screw down the plunger after use.

An overprimed engine can be cleared by opening the throttles, with switches off, and turning the airscrew backwards. The starting handle should first be turned backwards at least three revolutions to ensure that the worm gear will be out of engagement during the above reverse rotation of the engine.

Hot Starting.—When the engine is hot a slightly different procedure should be used, to avoid over-priming. The following procedure has been found very successful for hand starting.

(1) On taxying in, and prior to switching off, the engine should be run with the throttle fully closed for at least one minute, to allow the valves to cool down, and then switched off without opening the throttle.

(2) A restart can generally be made within fifteen minutes without recourse to priming if the throttle is opened very slightly, but not moved to and fro, which would cause petrol to be discharged from the accelerator pump, if fitted.

(3) If the machine has been standing for more than fifteen minutes, prime the engine in the usual way, as though starting from cold, but without turning the engine to " suck in." This should be done five minutes before it is required to start the engine. When a start is required, the engine must be turned slowly with the switches off, and without further priming. After two or three revolutions, the ignition can be switched on and the engine turned at normal speed, when it will generally start immediately.

RUNNING THE ENGINE.

The take-off of an aircraft is a manœuvre demanding the maximum available power from its engine, or engines and, moreover, one in which reliability of operation is of more than usual importance. For this reason, the ground running of the engine prior to take-off should be carried out with two main objectives, firstly to ensure that the engine, oil, and water temperatures are suitable for running at take-off power, and secondly to test as far as possible the correct functioning of the engine.

After ensuring that the water system has been topped up after a preliminary ground run, as described, the engine should be restarted and the following points observed :—

(1) The oil gauge should register a correct pressure. This may be high, initially, under cold conditions, but will fall to normal as the oil warms up.

(2) The oil pressure being correct, the engine should be run for the first two minutes at 800 R.P.M. with the radiator "in," if of the retractable type, or with shutters closed if the radiator temperature is shutter-controlled.

(3) The speed should then be increased to 1,300 to 1,400 R.P.M. in order finally to warm up, *i.e.*, until the water is about 70°C., and the oil about 15°C. at the inlet. It will then be safe to open the engine up to the "gate" or "take-off" position, in order to check revolutions, boost pressures, oil pressures, temperatures, etc., prior to flight. Single ignition checks can also be taken by switching off each magneto in turn, when the drop in speed should not be greater than 5 per cent.

(4) The radiators or shutters should be controlled to maintain a water or coolant temperature of about 80°C. during ground tests.

(5) Running at the gear or crankshaft "periods" must be avoided; viz., for the former, from about 820 to 1080 R.P.M., and for the latter about 1200 R.P.M.

(6) Running for excessively long periods on the ground at "tick-over" speeds, *i.e.*, about 400 R.P.M. should be avoided, unless an occasional burst of speed is given to prevent sooting up of the plugs and to circulate the water. The danger of running for long periods at a slow speed is due to the fact that the water is then only circulating very slowly, and if there be only one thermometer, and that in the "outlet" position, which is nearly always at the hottest point of the water system, *i.e.*, the header tank—this thermometer will only give the temperature of the water in the cylinders and header tank. The remainder of the water, however, especially in cold weather, and with the shutters open or the radiator "out," will be comparatively cold.

Should a pilot then attempt to take off without first running up the engine to ensure that the water is at an even working temperature and is circulating properly, it is probable that the cold water which will be pumped around the cylinder jackets will upset the carburation, and this fact, in combination with the possibility that the plugs will be sooted due to the prolonged slow-running, may cause the engine to cut out and result in a forced landing.

Where alternative fuel systems are fitted, all systems should, if possible, be checked.

TAKING-OFF, CLIMBING AND IN FLIGHT.

It is essential during all conditions of flight that the specified boost pressures and engine R.P.M. are not exceeded. For convenience of reference, the allowable boost pressures and speeds are tabulated (see page 355).

Before removing the chocks, prior to taking-off, the engine should be run up to check the R.P.M. at take-off boost, and also the drop in speed when each magneto is switched off in turn.

The take-off boost pressure must not be used for periods longer than 3 minutes, or the time taken to reach an altitude of 1000 ft., on climb, whichever is the lesser. The maximum R.P.M. for level flight, of 2900 R.P.M. (series IV. to XII.) or 3000 R.P.M., series XIV. to XVI., must not be used for more than five consecutive minutes.

Aircraft should not be flown at the maximum conditions for level flight except in emergency, or when necessitated by operational conditions. The total duration of "maximum level flight conditions" permissible per flight, in periods not exceeding five minutes duration, will vary with the operational requirements of the type of aircraft, but in view of the high engine stresses and increased oil and fuel consumptions, it should not exceed 10 per cent. of the total flying time.

"Over-boosting" of the engine is one of the most likely causes of internal leaks leading to cracking of the cylinder heads, loose valve seats, etc., and must at all times be avoided.

Economical Cruising.—The mixture should be weakened off until a drop in speed of approximately 2½ per cent. of the R.P.M. occurs, when the throttle should be opened to restore the original R.P.M.

Under these conditions of weakened mixture, the boost pressure on supercharged engines must not exceed –0·25 lb./sq. in. (series IV. to VI.) +1 lb./sq. in. (series VII. to IX.) or +1·25 lb./sq. in. (series XIV. to XVI).

Oil Pressure and Temperature.—The oil pressure should normally stand at 40 to 60 lb./sq. in., and the oil temperature should not normally exceed 80°C. at inlet. The engine should not be run with the pressure gauge showing less than 40 lbs./sq. in. at normal speed, with this inlet temperature. With very hot weather conditions an inlet temperature of 90°C. is permitted.

The pressure may be below 30 lbs./sq. in. when "idling" hot, and at above 80°C. inlet, but must build up to normal at approximately 1,200 R.P.M.

Water Temperatures.—The water temperature may be such that slight steaming occurs at the header tank vent (approximately 105°C.) with a pressure system, but only when climbing.

When a pressure system is used, the relief valve should allow a pressure of approximately +2½ lbs./sq. in., but must also allow admission of air when a depression to the extent of –½ lb./sq. in. obtains under cooling conditions. For normal flight the specified temperatures of 75° to 85°C. should not usually be exceeded.

When operated compositely cooled, the outlet temperature may be 94°C. in level flight, and may rise to 110°C. on climb.

FLYING CONDITIONS.

Type.	Series.	Take-off.			Climbing.		All-out Level.		Maximum Cruising.		Cruising on Weak Mixture.	
		Boost. lb./sq. in.	R.P.M.		Boost. lb./sq. in.	R.P.M.	Boost. lb./sq. in.	R.P.M.	Boost. lb./sq. in.	R.P.M.	Boost. lb./sq. in.	R.P.M.
			Min.	Max.								
Fully Supercharged	IV V VI	+6	2240	2500	$+1\frac{1}{2}$	2500	$+1\frac{1}{2}$	2900	$+\frac{1}{2}$	2500	$-\frac{1}{4}$	2500
Moderately Supercharged	VII VIII IX	F.T.	2375	2500	$+2\frac{5}{8}$	2500	$+2\frac{3}{8}$	2900	$+1\frac{1}{4}$	2500	+1	2500
Naturally Aspirated	X XI XII	F.T.	2375	2500	FT.	2500	F.T.	2900	...	2500	...	2500
Fully Supercharged	XIV XV XVI	+6	2225	2600	$+3\frac{1}{4}$	2600	$+3\frac{1}{4}$	3000	$+2\frac{1}{4}$	2600	$+1\frac{1}{4}$	2600

It is most important that sudden changes of temperature be avoided, such as may occur when diving, after a climb, for these temperature fluctuations are likely to impair the reliability of the cylinder top joints. Under these conditions, the temperatures should be regulated by the use of the radiator shutter or retractable radiator. The latest installations incorporate a thermostat, which ensures almost constant temperatures, and relieves the pilot of this duty.

PROCEDURE FOR STRIPPING.

During the process of dismantling, a very suitable opportunity is afforded for testing the backlash of gears and general wear and condition of parts. Items of importance should be carefully recorded.

It is essential that the engine should be mounted and secured in a cradle which is capable of permitting it to be rotated and locked in at least four positions, namely :—(1) The normal upright position ; (2) With the "A" side cylinder block vertical ; (3) With the " B " side cylinder block vertical ; (4) With the engine inverted.

The cradle should be so arranged that the longitudinal bearers and engine feet brackets do not obstruct removal and insertion of the lateral crankshaft bearing bolts. Lifting tackle is also necessary.

The recommended sequence of dismantling to reduce the engine to its principle components is as follows :—

Supercharged Engines.

(1) Airscrew Hub and Reduction Gear.
(2) Water Pipes.
(3) Priming and Volute Drain Pipes.
(4) Ignition Wires and Magnetos.
(5) Supercharger, Carburettor, Boost Regulator and Controls.
(6) Spring Drive, Hand Starter, Supercharger and Dynamo Drive Gears.
(7) Gas Starter Distributor.
(8) Rocker Covers and Camshafts.
(9) Upper Camshaft Drives.
(10) Wheelcase and Pumps.
(11) Induction Manifolds.
(12) Cylinder Blocks.
(13) Pistons.
(14) Crankcase Lower Half, Oil Pumps and Compressor.
(15) Crankshaft and Connecting Rods.

Normally Aspirated Engines.

(1) Airscrew Hub and Reduction Gears.
(2) Water Pipes.
(3) Priming Pipes.
(4) Ignition Wires and Magnetos.
(5) Controls.
(6) Dynamo Drive.
(7) Spring Drive and Hand Starter Gear.
(8) Gas Starter Distributor and Pipes.
(9) Carburettor and Induction Pipes.
(10) Rocker Cover and Camshafts.
(11) Upper Camshaft Drives.
(12) Wheelcase and Pumps
(13) Cylinder Blocks.
(14) Pistons.
(15) Crankcase Lower Half, Oil Pumps and Compressor.
(16) Crankshaft and Connecting Rods.

For the dismantling of the engine to units, to be described, special spanners, extractors, jigs, and other tools are produced by the engine manufacturers. The prefix (S) refers to Supercharged engines and (U) to Unsupercharged engines.

Airscrew Hub and Reduction Gear.

S. and U.—The hub can be removed with a special spanner, and a cap should be fitted to protect the thread on the shaft. The backlash of the gears can conveniently be checked at this point.

The oil pipe to the reduction gear jet should next be removed and the two bolts from the top of the front half casing for attachment of the special lifting-jig. The reduction gear unit can then be lifted clear (see Fig. 59) when all the bolts round the facing have been removed together with the bolt through the boss on the breather casing.

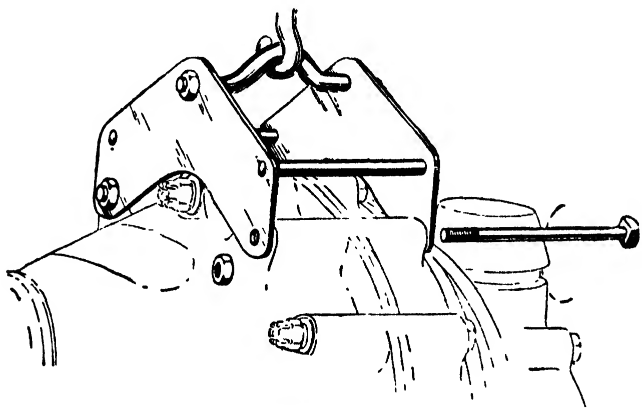


Fig. 59.—Lifting Reduction Gear.

The drive coupling from the crankshaft to the pinion should be withdrawn and a special tool attached to the crankshaft front end to turn the crankshaft when required.

Water Pipes.

S. The removal of the rear main bearing lateral bolt (G) (see Fig. 28) releases the main support bracket for the side water pipes, which can then be removed, together with the top water pipes, by undoing the necessary unions.

U. The side pipes can be removed in a similar manner to those on the supercharged engine (see Fig. 40). The top central water pipe can only be removed by slacking back the eight union nuts and sliding the two short connecting pipes (K), together with the corresponding pipes at the front of the engine, into the cylinder connections.

It is advisable when this has been done, to add temporary covers to the water pump outlets, to prevent small parts from falling in which might damage the impeller in service.

Priming and Volute Drain Pipes.

S. The two pipes from the main priming connection and volute drain, should first be disconnected, then, after removing the clips, dual connections, and atomizers, the piping unit can be removed complete.

Priming Pipes.

U. The priming pipes can be removed complete with the carburettor, or may be removed separately by unscrewing the cap nut on each manifold and taking out the four atomizers. After disconnecting the main feed pipe, and unscrewing the cap nut from each side of the central air intake, the pipes may be lifted away.

Ignition Wires and Magnetos.

S. and U. The ignition wire brackets and clips on the cylinder blocks and induction manifold should first be detached and the magneto distributors can then be detached by undoing the screws (G) (Fig. 60). After disconnecting the controls the magnetos can then be removed.

Before disconnecting the H.T. leads, it should be confirmed that both ends are correctly marked, to assist in re-assembling the engine.

Supercharger, Carburettor, Boost Regulator and Controls.

S. This assembly can be removed as a unit by first disconnecting the water and oil connections. The gland nut of the induction pipe connection should then be unscrewed, and when the retaining nuts have been removed the whole unit can be detached from the engine.

Controls.

U. When the top ball joint of the mixture control lever, and the rear universal joint in the throttle spindle, have been disconnected, the control bracket and controls can be removed from the wheelcase.

Dynamo Drive.

U. This unit can be detached by removing the retaining nuts, and the oil feed pipes.

Spring Drive and Hand Starter Gear.

U. After removing the nuts from the rear bearing housing, the unit can be withdrawn complete.

Spring Drive, Hand Starter, and Dynamo Drive Gears.

S. and U. The casing can be removed complete after unscrewing the retaining nuts. Care must be taken that the four gears, which are freely mounted on floating bushes, do not fall out. The hand starter gear and spring drive will come away with the casing.

Carburettor and Induction Manifolds.

U. The two Petroflex fuel drain pipes and two water connections to the pump inlet should first be disconnected. The assembly can then be removed as a unit after unscrewing the nuts from the vertical studs securing the carburettors to the four side manifolds.

Rocker Covers and Camshafts.

S. and U. It is first necessary to remove whatever auxiliary unit is driven from the camshaft rear end. After withdrawing the coupling shaft, and unscrewing the retaining nuts, the rocker cover can be removed. There is no need to separate the rocker exterior covers. A convenient opportunity is afforded for measuring the backlash of the bevel gears. The camshaft brackets and rockers can be removed as a unit.

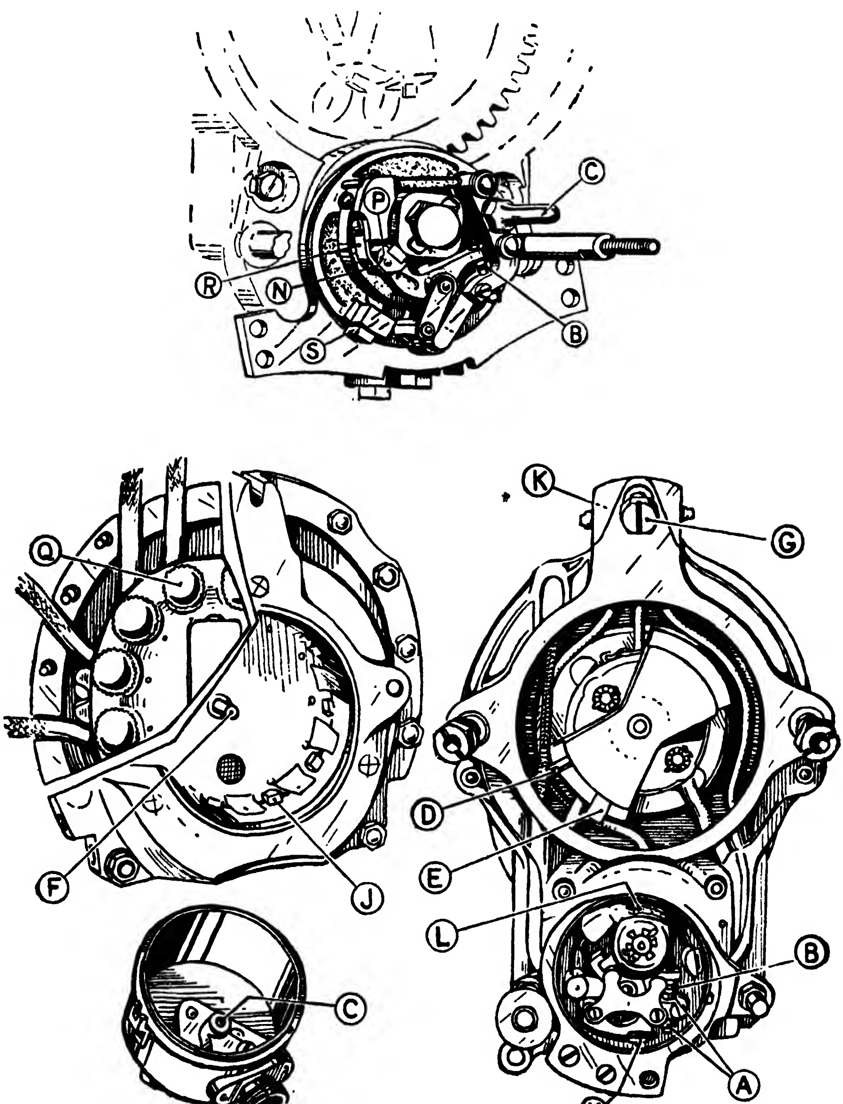


Fig. 60.—Magneto Contact Breaker with Distributor Removed.

Upper Camshaft Drives.

S. and U. (Fig. 26). Before removal of this unit it is necessary to free the casing (A.1) of the vertical shaft. This is accomplished by releasing the locking plate and unscrewing the lower serrated retaining nut over the lower camshaft drive casing. Similarly, the upper gland nut (M) should be unscrewed, after removing the locking clip (N). The top cover (C) retaining the drive shaft (D) is next removed, and the guard tube (A.1) can be slid up into the upper housing together with the drive-shaft (D) which should be lifted clear of the splines.

The whole upper drive unit can be tapped upwards, using a wooden (not metal) drift, after unscrewing the securing nut (B). The drive shaft (D) can then be withdrawn.

Wheelcase and Pumps.

S. and U. The wheelcase and pumps can be removed by detaching the camshaft and fuel pump oil pipes, and unscrewing the retaining nuts.

Induction Manifolds.

S. The central induction pipe can now be removed from the four side manifolds by unscrewing the tapping bolts. The side manifolds can either be removed at this stage or later.

Cylinder Blocks.

S. and U. It is essential to rotate the engine cradle until the cylinder block to be removed is vertical. The engine should then be rotated until pistons Nos. 3 and 4 are at T.D.C. This is necessary to avoid the possibility of scraper rings locking in the crankcase, which would occur with a piston at B.D.C., on removal of the block and liner.

After unscrewing the fourteen nuts from the holding down bolts, the lifting tool can be attached to the camshaft bracket studs (see Fig. 61) and the block lifted clear of the pistons. The block should then be bolted to the special cylinder jig shown in Fig. 62, to avoid disturbing the cylinder liners, and the holding down nuts tightened in exactly the same way as when assembling the block on the crankcase (see page 366).

The piston rings should be removed to avoid risk of breakage, and the engine cradle turned through 60° to bring the other block uppermost, care being taken that the exposed pistons and connecting rods do not fall over against the crankcase.

Pistons.

S. and U. One gudgeon pin locking ring should be removed from each piston and each pin pushed out by hand. If necessary a drift can be used after the removal of the other locking rings.

Crankcase Lower Half, Oil Pumps and Compressor Drive.

S. and U. The engine cradle should be swung over so that the engine is inverted. After removal of the main oil feed pipe and retaining nuts, the crankcase lower half can be detached. Care should be taken to preserve the four tubular dowels. The main oil gallery and connection to each main bearing can then be detached.

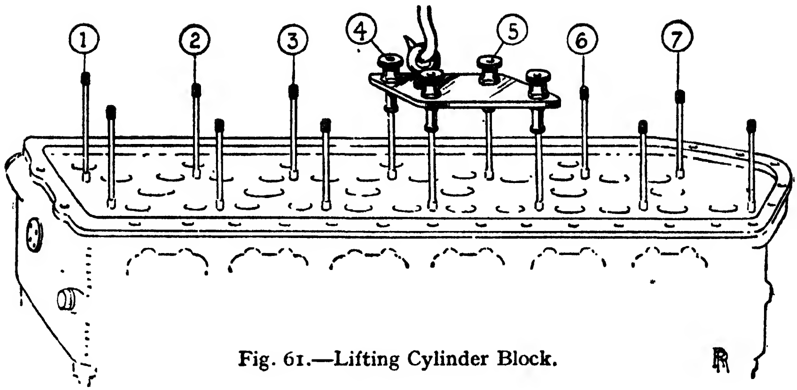


Fig. 61.—Lifting Cylinder Block.

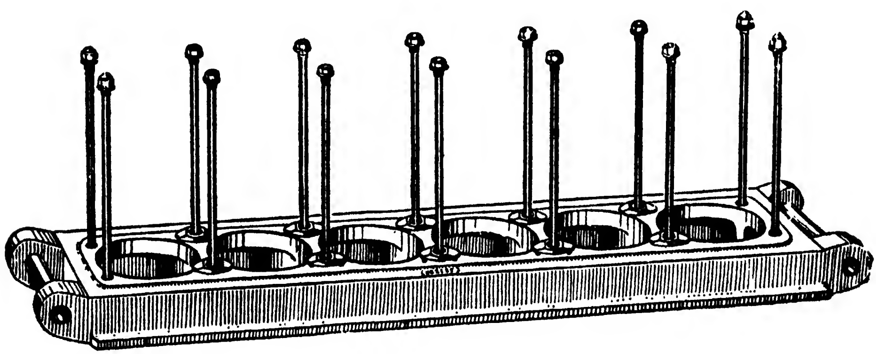


Fig. 62.—Cylinder Jig.

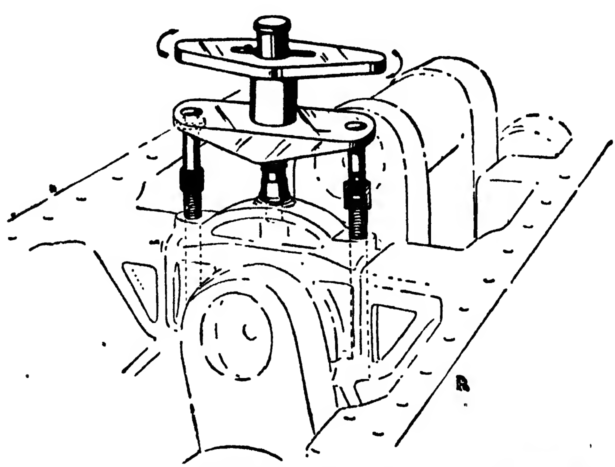


Fig. 63.—Extracting Main Bearing Caps from Crankcase.

Crankshaft and Connecting Rods.

S. and U. The lateral bolts and main bearing cap retaining nuts should first be removed. The caps can then be withdrawn by a special extractor (see Fig. 63).

A suitable trestle should be prepared for the crankshaft, which can be removed complete with connecting rods, care being taken to remove the upper half main bearing bushes which may adhere to the journals.

The plain rods must be removed first, using a soft metal drift to drive out the bolts. The forked rods can then be removed, and in order to facilitate reassembly it is advisable to reassemble loosely the connecting rod and big-end assembly.

If desired, the connecting rods can be removed while the crankshaft is still in position in the crankcase. As before, the plain rods should be removed first, which can be done by turning the crankshaft to bring each crankpin in turn to the top, to give better access to the split pins and nuts.

INSPECTION.

All units should be inspected for wear, and clearances and backlash checked wherever possible. The maximum clearances allowed by the makers should not be exceeded, otherwise new or oversize parts may be required.

In addition, all highly stressed parts should be inspected for cracks. Steel parts can be tested magnetically, and non-ferrous parts by the chalk test.

In the former test the steel part is placed between two magnetic poles and thereby magnetised. A special solution containing ferrous metal dust in suspension is poured over the part and the presence of a crack is denoted by a black line consisting of the black particles from the liquid.

The chalk test, for non-ferrous metals, consists of immersing the part to be tested in a mixture of lard oil and paraffin, at 80°C. to 90°C., for about 15 minutes. The part is then quickly dried, while still hot and dusted with French chalk. When the part cools, the presence of a crack is denoted by discoloration of the chalk, caused by oil exuding from the crack. Larger non-ferrous parts can be tested by painting with a mixture of methylated spirit and chalk.

The cracks which may be indicated by the methods detailed above may not appear serious when found, but in a highly stressed part it is possible for a crack, when once formed, to spread rapidly and cause failure.

ENGINE ERECTION.

Reassembling the Engine from Units.

The following general points should be noted during reassembly :—

(1) Where parts are numbered, the numbering commences at the reduction gear end of the engine.

(2) An excess of jointing compound on the jointing faces should be avoided, since it is liable to restrict any oil drillings or passages adjacent to the joint.

(3) All bearing surfaces should be freely lubricated with clean engine oil before assembly.

Crankshaft and Connecting Rods.

This assembly is most conveniently carried out by mounting the crankshaft on a suitable wooden trestle, and fitting the oil caps to the journals

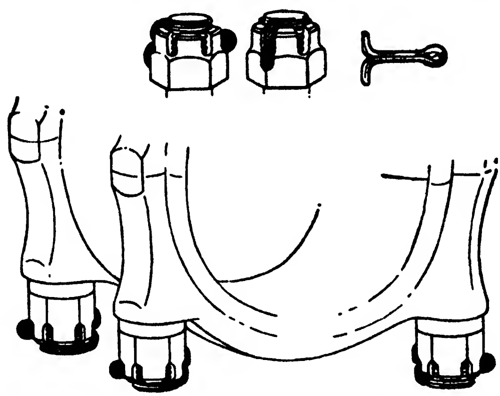


Fig. 64.—Correct Method of Fitting Split Pins to Connecting Rods.

and big-ends with the castellated nuts to the timing gear end of the engine. The connecting rods can then be assembled with the markings corresponding with those of the crank webs. After testing the rods for freedom on the crankpins, the split pins should be fitted as shown in Fig. 64. It is of vital importance that each should be a tight fit in the hole, and secured by opening, as shown. The small end floating bushes can also be checked for freedom in the connecting rods.

Crankshaft and Bearings.

For this operation the crankcase must be inverted, when the upper halves of the main bearing bushes can be replaced and the crankshaft and rods lowered into place, with the plain rods on "A" side. The bearing caps, which should be a light tapping or tight push fit, can then be smeared with vaseline on the flat bearing faces, and tapped into position. The vertical studs should first be nutted up and split pinned, and the lateral through bolts then inserted from "A" side, with the water connection bracket on the rear bolt. The oil gallery should be attached, using new aluminium joint washers and Heldite.

Oil Test of Crankshaft, Bearings and Connecting Rods.

This test is carried out with the engine still inverted, and its object is to ensure that the oil connections and crankshaft plugs are free from leaks and that oil reaches the big-ends of plain and forked rods, without excessive leak from the bearings. A source of pressure oil supply, such as a hand-operated pump with pressure gauge, is connected to the main oil feed on the crankcase, and standard engine oil at 25°C. to 90°C. pumped in to the system. After moving the crankshaft gently until oil flows from the rear journal, a special plug should be inserted in the rear of the crankshaft and the pressure raised to 80 lb./sq. in., and maintained. By turning the crankshaft the oil flow from the bearings can be inspected.

Pistons.

The piston rings should be fitted with the bright faces to the underside of the piston, in the same order as before dismantling. The pistons can then be assembled on the connecting rods by inserting the gudgeon pins, which are a push fit, and should be secured by two circlips, making a total of twenty-four circlips for the engine. The markings on the pistons, 1A to 6A, and 1 B to 6 B, must be observed, and the stop for the second ring (*i.e.* the top stop) should be towards the outside or exhaust side of the engine.

Cylinder Blocks.

It is assumed that the valves and springs are assembled in the block, which is attached to the jig shown in Fig. 62 with the liners in place. The engine cradle should then be turned so that one cylinder joint face is horizontal and at the top and the crankshaft rotated to bring cranks Nos. 3 and 4 to T.D.C. The crankshaft should not be turned again until the block is in position, or the rings may lock in the crankcase and be broken. Ten rubber joint washers should be placed, one on each stud tube ferrule at the lower end of the block.

The block can be lifted as shown in Fig. 61, and lowered on to the crankcase, care being taken to guide in pistons Nos. 3 and 4. Piston ring retainers should be fitted to all pistons. When the upper rings of these pistons have entered their respective liners the ring retainers can be removed and the scraper rings contracted by special forceps to allow the liner to be lowered over them. Pistons Nos. 1, 2, 5 and 6 can be similarly guided into their respective liners by lowering the block, and the piston ring retainers removed. The stage illustrated in Fig. 65 is then reached and the scraper rings can be contracted in turn and made to enter the liners, the process being assisted by very slightly tilting the block as shown, and commencing with the ring at the lower end.

After tightening the cylinder studs evenly and gradually as described below, the other block can be replaced in a similar manner.

Tightening of Cylinder Holding Down Nuts.

To secure uniform loading, it is strongly recommended that the special slipping spanner shown in Fig. 66 should always be used for nuts No. 1 to 10. The four end nuts being finally tightened by a box spanner with 9½ ins. tommy bar. The slipping spanner incorporates a spring loaded friction clutch, which slips at the safe maximum load, and tightening should be

carried on to this point. The setting of the clutch can be done by holding the spanner in a special jig and applying the requisite torque by means of weights on the end of an arm. Adjustment is carried out by sliding back the knurled sleeve and turning the hexagon headed cap. Although it is advisable to check the spanners regularly, it is usually found that one setting is suitable for several months' use. A ratchet automatically locks the clutch in the reverse direction.

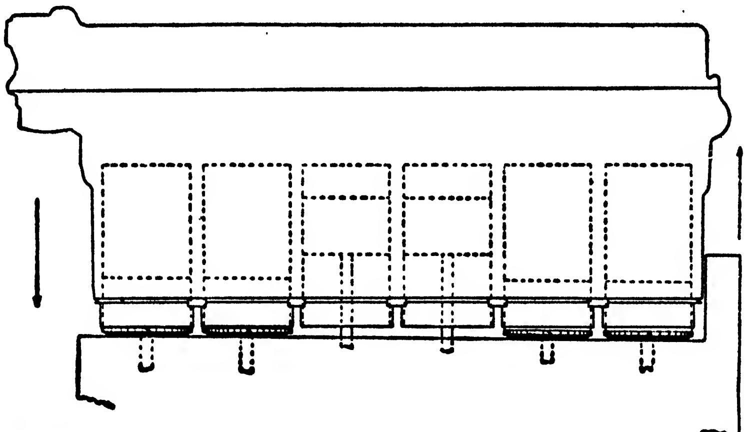


Fig. 65.—Tilting Cylinder Block to Facilitate Entry of Scraper Rings.

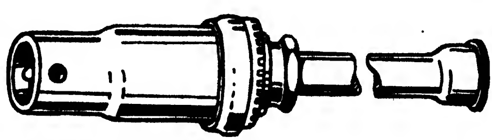


Fig. 66.—Slipping Spanner for Cylinder Nuts.

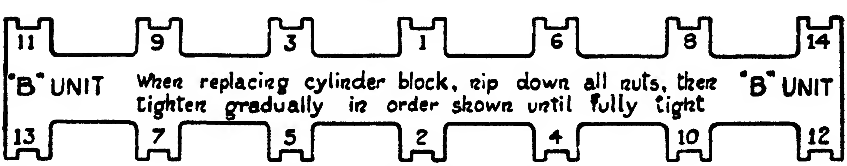


Fig. 67.—Cylinder Nut Template.

Fig. 67 shows the cylinder nut template, giving the order of tightening of the nuts. This is dropped between the camshaft retaining studs.

Crankcase Lower Half.

The engine should be inverted and the crankcase lower half, complete with oil pumps and vacuum pump drive, can then be lowered into place. All Vellumoid, or paper joint washers should be renewed before this operation, and the nuts on the four studs fitted with tubular dowels should be tightened first. After tightening the remainder of the nuts, the main oil supply pipe can be added to the left hand side of the engine.

Induction Manifolds.

The joint facings should be carefully examined and cleaned, and the Klingerit joints renewed if at all doubtful. The aluminium joints must be free from kinks and perfectly flat. Heldite should be applied sparingly to the latter joints, but no jointing should be used with the Klingerit. Care should be taken, when attaching the central manifold to the branch pipes, that the tapping bolts are not fouling the gaskets. The bolts should be pulled up uniformly.

On normally aspirated engines the carburettor and central manifolds can be replaced complete, as a unit. The two petrol drain pipes, and front and rear auxiliary water pipes, can then be replaced.

Wheelcase and Pumps.

This can be assembled as a unit, using a paper joint washer smeared with Heldite, but care must be taken to ensure that the pump gears are correctly meshed. The five clips for the camshaft oil feed should be put into position on the studs before replacing the nuts.

Spring Drive, Hand Starter and Supercharger Gears.

It is first necessary to insert the spring drive spindle, engaging the splines with those in the crankshaft. The spring drive and rear bearing housing, with paper washer, can then be slid into position and the housing nutted up to the wheelcase. The gears A, B, G and H (Fig. 35) should then be replaced. The procedure for unsupercharged engines is similar to the above, except that the gears referred to above are not included.

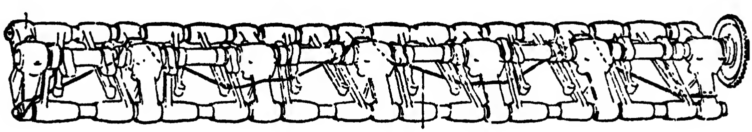


Fig. 68.—Method of Temporarily Securing Rockers.

Camshaft and Rocker Mechanism.

To facilitate replacement it is advisable to assemble the rockers, rocker-shaft and camshaft as shown in Fig. 68, and to secure the rockers with a cord or wire. The whole unit can then be lowered into position and pulled up with sufficient nuts to compress the valve springs. The brackets should then be tightened down evenly and the nuts split-pinned. There is no need, at this stage, to pay any regard to the valve timing, since this can be done by the quill shafts in the camshaft drive. The bevel gears can therefore be meshed in any position.

Valve Timing.

For the purpose of timing, each engine is provided with an inspection plug in the front end of the reduction gear housing, giving access to a timing disc on the pinion, with stationary pointer. It is, therefore, import-

ant that the pinion should be assembled in the correct relationship to the crankshaft, or these timing marks will be useless.

Timing of the camshafts is accomplished by setting the opening points of the inlet valves in cylinders Nos. A.6 and B.1, the corresponding marks on the pointer being Nos. A.6 I.O. and B.1 I.O. For the purpose of finding the opening point of a valve, greater accuracy can be obtained when the rocker bears some way up the side of the cam, for this reason the tappet clearance of the cam under consideration should be set to 0 035 in. (see (F) Fig. 23).

To time "A" side camshaft, the crankshaft is turned to the No. A.6 I.O. position and the serrated coupling shaft (D) disengaged. With a 0·005 in. feeler between the rocker and valve head of an inlet valve in A.6 cylinder (see sketch (G), Fig. 23) the camshaft is turned in the direction of the arrow, until the feeler is just tight, *i.e.*, until the valve is just opening. The clearance must have been first set to 0·035 in. as mentioned above. The serrated coupling, having nineteen and twenty-one splines to give a vernier effect, should now be turned until it will slide easily into place. The maximum error is just under 1°.

"B" side camshaft should be timed in a similar manner, using B.1 cylinder. To obtain the correct relationship between the camshafts, the crankshaft should be turned through 60°, in the direction of the arrow, to the B.1 I.O. position, and the B timing carried out at this point. All tappet clearances should then be set to 0·020 in.

Magneto Timing.

The magnetos are driven each from the cross shaft previously described, at one and a half times engine speed, by a vernier coupling with eleven serrations at one end and twelve at the other.

For supercharged engines the ignition timing at full advance should be set to 37° before top dead centre for both magnetos. In the case of naturally aspirated engines, "B" side magneto (port), firing the exhaust side sparking plugs is set 2° in advance of "A" side (starboard) magneto. The timing at full advance is then 36° early for "A" side magneto, and 38° early for "B" side.

When the valves have been timed, and the distributor covers and timing disc inspection plug removed, the engine should be timed as detailed below.

There are two alternative marks on the timing disc of supercharged engines by which the ignition timing may be set, A6MA and B1MA, as shown in Fig. 23. Either of these marks can be used. If the engine is to be timed for A6 cylinder the crankshaft should be turned to bring the A6MA point in line with the pointer. It should then be confirmed that the valves in A6 cylinder are closed, to ensure that this cylinder is on its firing stroke. If the exhaust valves are still open, the crankshaft should be turned through 360°.

The distributor of "A" side magneto should then be turned to the A6 position, as shown in Fig. 48, and the contacts, which should have previously been set to a gap of 0·012 ins., turned until they are just on the point of opening, with the cam ring in the full advance position. The point of opening can best be determined with a battery and bulb in circuit

with the contacts. Without turning the magneto the vernier coupling H (Fig. 23) should be tried in various positions, until both ends engage with the splines, and the magneto pushed into position and nutted up.

In the case of supercharged engines, "B" side magneto can then be fitted in exactly the same way, without turning the engine. For unsupercharged engines there are two pairs of markings on the timing disc allowing "B" side magneto to be set 2° advance of "A" side magneto, as referred to above, and the engine crankshaft must therefore be turned back 2° from the "A" side timing mark to the second mark on the timing disc. "B" side magneto can then be timed to spark on the A6 cylinder, and meshed with its coupling shaft in a similar manner.

Fitting of Cylinder Liners.

In the event of an internal water leak at the top joint, or an external leak at the bottom rubber joint, the cylinder block must be removed, taking care not to disturb the liners. In any case the following procedure must be carried out as a routine operation, when giving the engine a major overhaul approximately every 400 hours. Various special tools and gauges are required, and are referred to in the text.

It is first necessary to pressure test the block under water, to find the exact nature and location of the suspected leak. The recommended procedure is as follows :—

(1) After removing the block from the engine, it should be bolted down to the special jig shown in Fig. 62, and the nuts securely tightened.

(2) Blanking plates should be fitted to the water inlets and outlets, arranging for a compressed air supply at 30 lbs./sq. in. at one of these points. This pressure should not be exceeded.

(3) The block is then immersed in water at 80° to 90°C. and inspected for leaks. Points requiring particular attention are :—(a) Top joint rings ; (b) bottom rubber joints (to be renewed in any case when re-assembling) ; (c) all inlet and exhaust manifold studs (leaks can be cured by removing the stud and smearing the thread with Heldite before replacing).

(4) The liners can then be removed from the block, and since this is facilitated by the block being hot, it should be removed from the jig as quickly as possible and the liners extracted by means of a special tool which grips the flange at the base.

After carefully labelling each part with the number of the bore, the liners can be put on a faceplate and the top joint face checked for distortion. If this exceeds 0·0005 in., the liner should be skimmed up. If this is done, however, the remaining five liners in the block must be skimmed up the same amount, and oversize joint rings used to bring the overall length back to standard. All liners are marked either S to indicate that they are of standard length, and $S+\frac{1}{2}$, or $S-\frac{1}{2}$, and so on, to indicate that they are over or undersize to the extent of 0·0005 in., or half of one thousandth part of an inch. Where replacements are required, these should be selected with the same markings as the old liners.

The joint ring seatings in the block must now be inspected for pitting or damage marks, in conjunction with the leakage record. It is sometimes found after service that a block is "bowed," that is, concave or convex along its major axis. This is shown by the fact that the joint ring facings

in the cylinder head are not in one plane, resulting in unequal loading on the cylinder liners when the block is tightened down. This can be checked by inverting the block and placing it on a special jig on a flatplate. Any rock between the block and jig should be taken up by inserting metal foil. The level and alignment of each facing can now be compared by using a special depth gauge fitting on the joint facing, and running a clock indicator round the upper face of the gauge. If the block is bowed to the extent of more than 0·008 in., it should be rejected. The maximum permissible variation of the base flanges of the liners from one plane, when finally trued up and assembled, must be less than 0·0005 in.

The lowest facing must first be trued up by a face cutting tool, and the other facings trued up to this level. The facings should then be lapped with a special tool, and finally checked with the dial indicator. If satisfactory, the liners can be lightly lapped, each in its own bore, and assembled with top joint rings for checking the alignment of the liner base flanges. A record should be kept of the amount which is cut from each facing, and oversize joint rings used. For example, for cuts up to 0·005 in., standard joint rings can be used, but for cuts between 0·005 in. and 0·010 in., a 0·005 in. oversize joint ring should be used, and so on, up to 0·025 in. After reassembly, the block should be pressure-tested for leaks as before.

Replacing a Cylinder Stud Tube.

If a cylinder stud tube is found to be leaking, and slightly tapping the ferrule further in does not cure it, the tube must be removed and a new one fitted.

When a power drill is available, the ferrule and tube can be machined away at one operation, using a special drill. The inner portion of the tube can then be hammered out.

If hand tools only are available, however, the ferrules should be screwed in turn with a suitable tap (18m. sparking plug), and a plug inserted to enable the ferrules to be hammered out with a rod inserted from the opposite end. Each tube end should now be drilled approximately 1 in. deep, using a special spigotted hand drill, which allows the taper portion of the tube to collapse when hammered with a shouldered drift.

The new tube can now be fitted and it should be noted that no jointing compound may be used. After driving the tube into position, the ends should be swaged out until the special gauge can be inserted. When both ends have been swaged, the tube ends can be brought down flush with the surface. Blanking plugs should be inserted in the bore of the cylinders before swaging the bottom ends, to prevent distortion.

The tube ends should now be reamed out until the ferrules can be pushed in to stand 0·080 in. or 0·090 in. proud, when they can be driven home, starting with the camshaft end ferrules.

Testing.

Every " Kestrel " engine is manufactured and tested in accordance with conditions laid down by the Aeronautical Inspection Directorate of the British Air Ministry, under whose authority a Certificate to this effect is given with each engine. The tests comprise a run of two hours duration at 90 per cent. of the rated power, after which the engines are stripped

and every detail carefully examined. The engines are then re-erected and submitted to a final test of one half-hour's duration, and during the last five minutes of this test the engines are opened up to full throttle. Details of the tests are entered in the log books supplied with each engine.

For particulars of Type, and other tests, the appropriate Air Ministry publication should be consulted.

ROUTINE MAINTENANCE.

Daily Attention.

1. Examine all pipes and connections for leaks.
2. Test control mechanism.
3. Inspect water level in system and observe precautions against frost.

N.B.—The maintenance work necessary at each period of flying time is all additional to that at the shorter periods preceding it. Thus at 120 hours the maintenance work detailed at 10, 20, 40 and 120 hours must all be carried out.

After 10 Hours' Flying.

1. Inspect magneto contact breakers. Gaps should not exceed 0·013 in. with rocker on peak of cam (0·011 in. minimum).

2. Lubricate all engine controls. Insert oil (D.T.D. 44B.) through lubricator, with a Tecalemit oilgun, and lubricate the flexible drive for dynamo (supercharged engines) by inserting, either oil (D.T.D. Spec. 109), or Air Ministry Standard grease.

3. Screw down water pump lubricator one revolution. Should leaks occur at gland, screw gland nut up (left-hand thread) when engine is hot, by hand only. No tools must be used.

After 20 Hours' Flying.

Clean the pressure pump suction oil filter, the main petrol filters, and the slow-running filter on supercharged engines.

Remove and inspect ignition plugs. Gaps should not exceed 0·015 in. (0 012 in. minimum).

Clean the magneto contact-breaker housing and spigot, smear with a good high melting point grease, and ensure perfect freedom of rotation.

After 40 Hours' Flying.

1. Disconnect and well flush out the fuel piping which connects the main filters to the carburettors until all the foreign matter is removed.

2. Examine valve springs for breakage.

3. Inspect tappet clearances and reset if necessary to 0·020 in. cold.

4. Drain and refill the system with fresh oil. The greatest care must be taken when refitting filters to see that all joints are sound and clean. New joint washers must be used if the old ones are at all doubtful, and excessive tightening to secure a good joint must be rigorously avoided. All joint faces must be scrupulously clean before re-assembly.

5. Observe lubrication instructions on magneto.

6. Remove triangular cover (two nuts) from boost regulator, towards rear end, and insert approx. one teaspoonful (3 5 cc.) of oil (Spec. D.T.D. 44B), to lubricate the piston guide.

7. Close throttles, and remove air balance pipe below changeover cock of boost regulator. With suitable syringe and oil (Spec. D.T.D. 44B),

inject approximately one teaspoonful (3·5 cc.) of oil upwards through connection hole to lubricate changeover cock and aneroid piston valve.

After 120 Hours' Flying.

It is recommended that the cylinder holding-down nuts be checked for tightness after 120 hours' running, and to do this it will then be necessary to remove the camshaft and rocker mechanisms. If the bevel gears are suitably marked, re-timing will not be necessary when replacing the units.

The template showing the order of tightening the cylinder nuts, obtainable from Messrs. Rolls-Royce Limited, as referred to in the Section on " Engine Erection," should be used, and it is important that this order be observed. Each nut must be gradually and evenly tightened, and for this purpose the special spanner having a predetermined slip or torque has been developed and is recommended by the engine makers.

Replacement of the camshaft and rocker mechanism is facilitated by tying up the rockers temporarily as indicated in Fig. 68.

If the special box spanner is used, no extension must be fitted on the nine-and-a-half inch tommy bar, and excessive tightening to cure a leaking joint is strictly forbidden.

Renew ignition plugs.

After 400 Hours' Flying (Supercharged Engines).

After 500 Hours' Flying (Normally Aspirated Engines).

It is recommended that, normally, after this period of flying, the engine should be removed from the machine for complete dismantling, decarbonising and inspection. This period, however, is, subject to modification, depending upon the behaviour of the engine and the way it has been handled. For instance, if a noticeable reduction of power should be apparent or should there be evidence of a defective bearing it would be advisable to dismantle the engine before the period specified.

A defective bearing is usually revealed by very low oil pressure, a sudden rise in oil temperature, or by a quantity of metal in the filters, but the latter should not be confused with duralumin chippings which may be due to faulty handling of the hand starting gear, or from other sources. A quantity of copper particles, however, is a certain indication of bearing failure, although the latter may also exist without this indication. It is advisable, therefore, to check the nature of any metal particles by a chemical test, to be made as follows :—Carefully clean the metal particles in petrol to remove oil, and then dry. Spread the metal dust out in a shallow dish and pour over it a ten per cent. hydrochloric acid solution, cold (standard dilute solution), or a solution of ten per cent. caustic soda, cold.

If duralumin, or aluminium alloy, the metal shavings will be visibly attacked. Lead or white metal from the supercharger bearings will show no visible reaction. The particles may, of course, be a mixture of both duralumin and lead or white metal. If well spread out, as indicated, this will be observed. When not in use the acid solution must be kept in a properly stoppered bottle, as its fumes will rapidly cause rusting of any neighbouring exposed steel parts.

INDEX.

SECTION I.

Part 1.—ARMSTRONG-SIDDELEY—"CHEETAH."

PART 2.—BRISTOL—"PEGASUS."

SECTION II.

PART 1.—DE HAVILLAND—"GIPSY MAJOR."

PART 2.—NAPIER—"DAGGER."

SECTION III.
ROLLS-ROYCE—"KESTREL."